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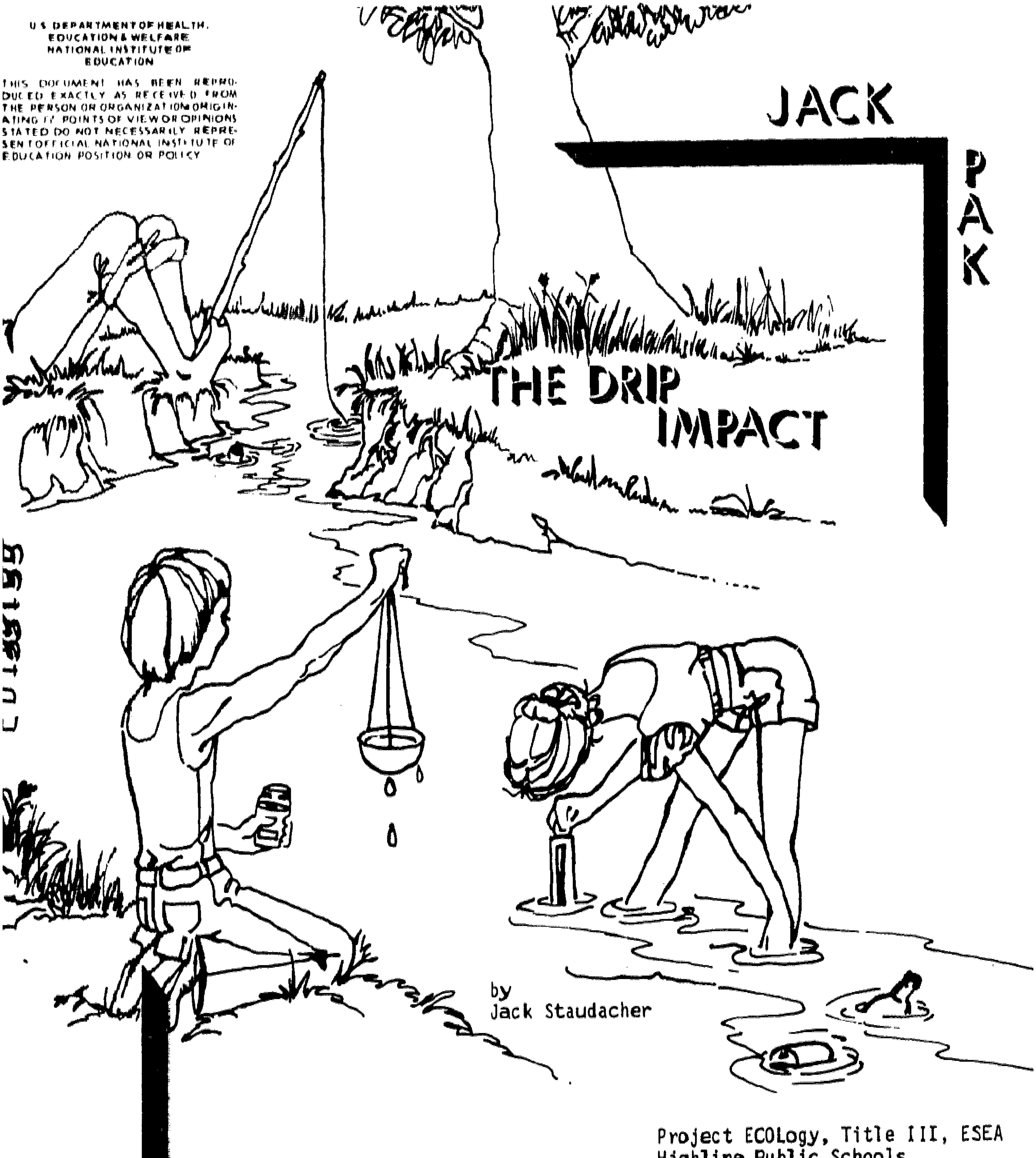
ABSTRACT

This is one of a series of units for environmental education developed by the Highline Public Schools. The unit is designed for senior high science classes. The primary emphasis of the material is on water, water analysis, and possible methods of watershed management; while the materials were designed for use in and around the Highline Public School District, the materials and ideas can be very easily adapted to any high school area. The suggested time for the unit is approximately three weeks. In addition to the lesson plans, there is a variety of reference materials and materials for transparencies. (RH)

# JACK PAK

# THE DRIP IMPACT



by
Jack Staudacher

An Environmental Learning Experience for Senior High Science. One of many "ELE PAKS" available for all areas.

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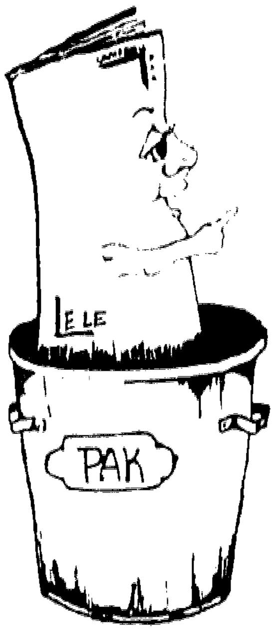
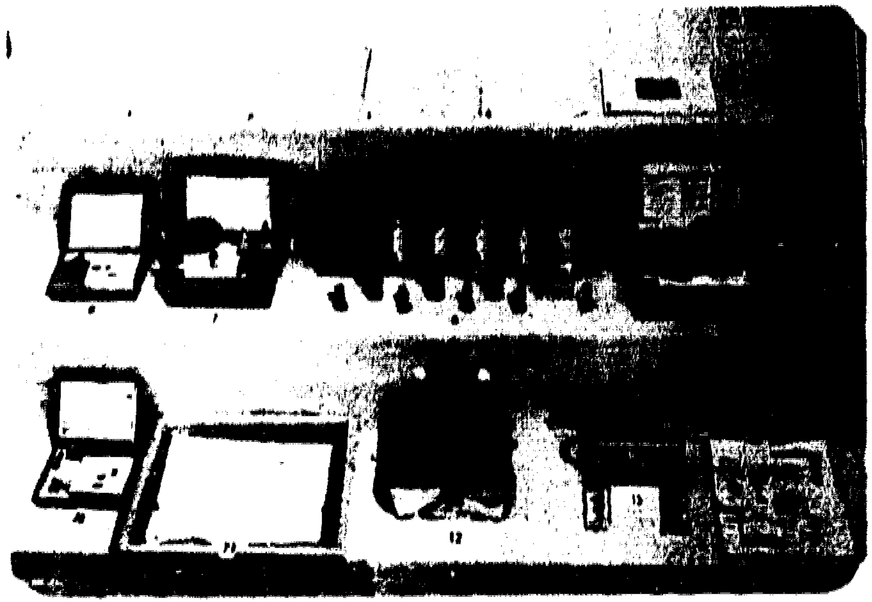


# Water Quality Sampling

by Jack Staudacher

| Photo Item | Amt. | Description | Source |
|---|---|---|---|
| 1 | 1 | Humidity table | H |
| 2 | 1 | Bacteria Test Instructions | H |
| 3 | 1 | Water Analysis Instructions | H |
| 4 | 1 | BOD Apparatus Instructions | H |
| 5 | 1 | Sea-Tac Communities Plan Booklet | P |
| 6 | 1 | pH Test Kit | H |
| 7 | 1 | Dissolved Oxygen Test Kit | H |
| 8 | 1 | BOD Apparatus Test Kit | H |
| 9 | 1 | Total Phosphate Test Kit | H |
| 10 | 1 | Nitrate Test Kit | H |
| 11 | 1 | | H |
| 12 | 1 | Surber Sampler | WI |
| 13 | 1 | Heatab Cook-it | |

## BACKGROUND INFORMATION

Water and Water Problems:

Of all the earth's resources none is more fundamental to life than water. All living things, both plant and animal, depend on water for their survival. Without it, death is the eventual outcome.

Water is one of the most abundant compounds on the earth. But 97% of this world's water is salty, and most of the remaining 3% is locked up in polar ice and glaciers. What remains, is found in the fresh water bodies (lakes, streams, ponds, etc.) in ground water aquifers, in the atmosphere, and in the plants and animals which inhabit this earth. Nevertheless, the liquid fresh water on earth is sufficient to cover all the land surface to the depth of several hundred feet.

With such a vast supply of fresh water in the world, why is mankind so concerned about it? One reason lies in the fact that the largest supplies of fresh water are located in areas inhospitable to man such as the Amazon and Congo basins, the mountains, and the frigid and sub-frigid ice zones. Secondly, and perhaps more importantly is that water is always in motion and the quantity existing in any given place at any one time is always changing.

Water may be detained; in reservoirs, in the ground, or as glacial ice; but stored water evaporates, ground water seeps, and glaciers melt. Water flow is continuous, but irregular, both in time and in space. Water problems exist because man's demands must be met with a supply that is variable: in space, in time, and in quality. This irregular flow of water is ultimately related to weather and climate. Our restless atmosphere is the most active agent in the constant redistribution of Water on the earth's surface.

If man has had water problems in the past, he has had only a sample of the future. Populations are increasing and costs providing quantity, quality, and protection from extremes in regimen (stream flow) are climbing. Competing uses for the same water are increasing at private, local, state and even national boundaries. All measures of water resource management that can economically contribute to the expansion of pure, ample water supplies will be needed.

## DESIGN OF PAK OPERATION

TO THE TEACHER: This Pak is designed for high school use and its primary emphasis is on water, water analysis and possible methods of watershed management. Hopefully, these lessons can be integrated, either individually or together, into various courses (i.e. physics, chemistry, biology, etc.) already a part of the school curriculum.

Although this Pak was designed for use in and around the Highline School District the material and basic ideas herein can be very easily adapted to any high school in any given community.

The utilization of this Pak will be left up to the teacher involved. Lesson plans were developed individually so each could be used separately to develop a specific component of the water cycle or its management. However, it should be noted (particularily in Lesson 6) that some discussions and alternate activities rely on

knowledge and/or results obtained previously. A suggestion, therefore, would be to use the Pak as a total unit and in the succession given. Although this is not critical it will allow the full potential of each lesson to be realized.

Operation for the entire Pak is approximately as follows: (Lessons may vary in length from teacher to teacher, class to class. Depending on the amount of interest, discussion and activities involved.)

| | Time | Location |
|---|---|---|
| Lead up activities (Lessons 1-4) | 5-10 days | School and surrounding areas |
| In Field Activities (Lesson 5 | 1 full day | (a) Miller and Des Moines Creeks (sampling stations)<br>(b) School lab - analysis of samples |
| Follow up activities | 1-2 days | Classroom |

CONCEPTUAL LOG

1) Watersheds and their boundaries
2) The Hydrologic Cycle
3) Runoff; how it is generated by a watershed
4) Infiltration and storate of water in the soil profile
5) Freshwater ecology (Chemical & Biological framework of a freshwater stream)
6) Water Resource Management (approaches to the solutions of water problems)

# MASTER MATERIALS LIST
(by lesson)

1) Pencil
   Grid paper
   50' tape measure (as many as possible)
   straight edge
   12" ruler
   U. S. Geological Survey Maps (Des Moines Quadrangle - 7.5 minute series: one for each student)

2) balance
   single beam
   center pivot
   large sponge(s)
   plastic sandwich bag(s)
   strong light sources
   pencil
   paper
   sling psychrometer(s)
   dew point and relative humidity tables

3) pencil(s)
   paper
   50' measuring tape(s)
   graph paper
   straight edge

4) three types of oven dried soil
   funnel(s)
   filter paper
   water
   beakers
   pencil
   paper

5) Velocity of Flow
   Method 1
      a. stop watch
      b. known length of string
      c. buoyant object such as an orange float or a styrofoam ball
   Method 2
      a. a straight flat bar of metal or wood
      b. two nails or pegs
      c. meter stick

   Volume of Flow
      a. stop watch
      b. float
      c. tape measure

   Temperature
      a. thermometer ($C^o$)

   Dissolved Oxygen (Hach Kit)
   Should contain following
   * (1) Dissolved Oxygen 1 Powder Pillows Cat. #981-99
   * (1) Dissolved Oxygen 2 Powder Pillows Cat. #982-99
   * (1) Dissolved Oxyten 3 Powder Pillows Cat. *987-99
   * (1) Dissolved Oxygen PAO (Dropper 4 oz. bottle) Cat. *1079-13

* Replacements needed

| | |
|---|---|
| (1) Glass stoppered DO bottle, 60 ml, with 30 ml mark | Cat. #619-00 |
| (1) Square mixing bottle | Cat. #439-00 |
| (1) Plastic measuring tube, 5.83 ml | Cat. #438-00 |
| (1) Large clippers | Cat. #968-00 |

Biochemical Oxygen Demand

(1) Laboratory Instrumentation Manual (Manometric BOD Apparatus Model 2173)
(1) BOD Data Charts

Equipment: BOD Apparatus, Model 2173

| | |
|---|---|
| (5) Pint glass bottles | |
| (5) Magnetic spin bars | |
| (5) Glass bottles with Mercury | |
| (5) Seal cups | |
| * (1) Tube stopcock grease | |
| * (1) 4 oz. DB Potassium Hydroxide 45% No. | Cat. #230 |

Coliform Bacteria Test

Presumptive Tube Assembly

| | |
|---|---|
| **(10) Lactose Broth Medium | Cat. #367 |

NOTE: Replace after each use.
Teacher: Order replacement for items used

Coliform Confirmation Test Kit

| | |
|---|---|
| **(10) Lactose Bile Broth | Cat. #322 |
| (1) Dri-bath incubator for five coliform tubes | |
| (1) Coliform bacteria test manual | |

| | |
|---|---|
| Nitrate Test Kit, 0-50 mg/l Model NI-11 | Cat. #1468-03 |
| * (2) Nitra Ver v Nitrate Reagent Powder Pillows | Cat. #14035-99 |
| (1) Clippers (for opening pillows) | Cat. #936-00 |
| (1) Color comparator | Cat. 1732-00 |
| (2) Color Viewing Tube | Cat. #1798-00 |
| (1) Dropper, plastic 0.5 and 1.0 ml marks | Cat. #2122-00 |
| (1) Nitrate Color Disc | Cat. #14038-00 |
| (2) Rubber stoppers for color viewing tubes | |

| | |
|---|---|
| Total Phosphate Kit Model PO-24 | Cat. #2250-01 |
| * (1) Demineralized Water (4 oz.) | Cat. #272-28 |
| * (1) Phosver III Phosphate Reagent Powder Pillows | Cat. #2125-99 |
| * (2) Potassium Persulfate Powder Pillows | Cat. 2451-99 |
| * (1) Sodium Hydroxide solution 5.0 N | Cat. #2450-37 |
| * (1) Sulfuric acid solution 5.25 N | Cat. #2449-37 |
| (1) bottle, mixing, glass 20 ml mark | Cat. 660-00 |
| (1) bottle, mixing, glass, unmarked | Cat. 439-00 |
| (1) Large clippers | Cat. #968-00 |
| (1) Color comparator | Cat. 1732-00 |
| (2) Color viewing tubes | Cat. 1730-00 |
| (1) Dropper 1 ml | Cat. #1282-37 |
| (1) Dropper, plastic 0.5 and 1 ml marks | |

* Replacements Needed
** Replacements Needed 5 ea./use

| | | | |
|---|---|---|---|
| Broken* (1) | Filter aid solution | 1 oz DB (dropper bottle) | Cat. #1046-33 |
| * | Filter paper folded | 12.5 cm | Cat. #1394-57 |
| (1) | Flask, Erlenmeyer | 50 ml | Cat. #505-41 |
| (1) | Funnel, plastic | 65 mm | Cat. #1083-67 |
| * (1) | Heatab cook-it | | Cat. 2207-00 |
| (1) | Wire test tube holder | | Cat. 634-00 |
| (2) | Stoppers (for color viewing tube) | | Cat. 1731-00 |
| (1) | Support for cook-it | | Cat. 2179-00 |

Wide Range; pH test kit

Model 17-N pH test kit

| | | | |
|---|---|---|---|
| * (1) | Wide range 4 indicator | 4 oz. dropper bottle (DB) | Cat. #216-13 |
| (2) | pH color viewing tubes | | Cat. #1926-00 |
| (1) | Wide range pH color disc | | Cat. #1919-00 |
| (1) | Color comparator box | | Cat. #1732-00 |

Benthic Sampling

(1) Surber Sampler
(1) Ekman Dredge with (1) Ekman dredge handle
(5) Wire baskets (barbecue type)

* Replacements Needed

HISTORY OF MILLER CREEK

Miller Creek begins its journey to the sea just north of the Seattle-Tacoma Airport. From this origin it meanders southwesterly to it's estuary in Puget Sound at Normandy Park Community Beach. The small pools and gently rolling riffles of this stream are fed by Burien and Tub Lakes found in the upper reaches of the watershed. Similarily, numerous springs add to the water supply as they bubble continuously along the watercourse.

Over the years this tiny stream's cold clear water has carved out a small channel in the dense lowland vegetation. This channel twists and turns until finally bathing a butter and geoduck clam bed upon its exit into salt water.

Twenty five years ago when Gene Wiseman built his house, Miller Creek was still clear and clean. He remembers when he and his children used to lay down and drink water from this tiny stream. Likewise, many of the homes along the stream were built 30 or more years ago. The majority of these early residents along the creek made considerable effort to retain a natural pleasant setting adjoining the stream. Old timers in the area can tell fish stories of excellent trout fishing and remember large spawning runs of coho salmon. This was a time when much of the airport area was small farms and orchards and the Burien business district clustered around 152nd and Ambaum. This was a time of lush vegetation, clear water and clean air. A time that would soon pass.

In the fifties the Highline area began to develop rapidly. Lots of new homes were built. The King County Planning Commission instituted a Burien Business District Expansion Study on March 1958. The basic premise of which was to establish Burien as a regional shopping center. Houses gave way to commercial development. Small farms and open areas were sub-divided into residential areas with many houses on small lots. These houses put in septic tanks for waste disposal, but the tanks soon failed, seeping into storm drainage ditches which soon found their way to the creek. It became evident that sewers were needed to help keep Miller Creek clean. Some of the area was sewered immediately and in 1965 construction was begun on a sewage treatment plant one half mile upstream from the creek's mouth. A main sewage collection line was laid down the creek ravine from Des Moines Way South to the treatment plant. At this time, the Washington State Fisheries gave specific criteria and recommendations as to construction specifications along the stream so as not to damage the spawning characteristics of the creek. The course of the stream was changed as it passed through the site of the treatment plant and it was required that a fish ladder be provided through this area.

In the 1960's the Burien business district continued to explode. Burien Shopping Plaza laid down acres of blacktop. GovMart Bazaar, Bells and other agencies covered acres of land with concrete all along First Avenue.

In 1968 White Front paved over a 10 acre parking lot. In most cases no effort was made to storm sewer any of the run-off water away from the stream. Nor did building requirements call for any regulations that would slow down the run-off water from these new developments and/or limit the amount of impervious surface installed. (It is interesting to note that the King County Planning Department stated in the 1964 Comprehensive Plan for King County Wash: "Urban growth must be logically planned. It should be related to and integrated with the natural environment--not superimposed over it.")

Even though this development was changing the stream and the waters had become polluted and undrinkable the stream was still supporting fish life and the outward characteristics of the stream remained pretty much the same. The water was clear, the stream bed was still gravelly. Periwinkles, crawdads and fish were common and erosion along the banks was still controllable.

In 1967 Urban Arterial Funds were established and street "improvements" in the Highline Area mushroomed. Criteria established for these improvements included curbs, sidewalks and underground storm sewers. Implementation of storm sewers resulted in a quick piped system of run-off instead of the much slower ditches. It may be advantageous in most instances not to have to cope with open ditches, but the now collected and piped run-off goes very much faster to its receptable - in this case Miller Creek.

In 1968 the Airport started a major expansion. They removed many houses, a holly farm, and drained Evergreen Lake. Soil needed to fill in the new runway was in excess of 3 million cubic yards and no effort was made to control the flow of excess silt into the nearby creek. In 1969 the State Highway began construction of the continuation of Highway 509 from 128th to 166th and Highway 518 east to west at the north end of the Airport. Again the State Highway did nothing to hold back or control the silting of the stream during construction. Then in 1970, Washington State Fisheries stated that the stream had become too polluted to continue stocking with salmon. Mr. Jim Ames on March 30, 1970 of Washington State Dept. of Fisheries, stated in a report after a survey of the stream had been completed, "The factor contributing most to the stream's deterioration is the excessive amount of fines (sand and silt) in the bottom material...(This sand and silt made up between 70 and 100 percent of the bottom composition.) This condition is so acute that successful spawning is virtually impossible...." (It seems strange that the State Fisheries could demand a certain criteria of construction from the sewer district in 1965 but in 1968 they were unable to enforce any regulations with the State Highway or Airport.)

In February 1970, Miller Creek residents of Normandy Park were contacted and asked to sign easements with King County Flood Control granting them the right to enter the property to make stream improvements. No one would sign until they were told what the improvement would be. It was then they learned their eight to ten foot stream would have to be widened up to seventy feet to accomodate a projected peak flow of 1280 cubic feet per second. That is six times the natural capacity of the stream which is or was historically about 200 cfs peak flow. A number of residents in Normandy Park did not agree that a seventy foot ditch was property improvement. It was felt that a ditch of this size would leave an enormous ugly scar through the community, kill all fish life in the stream, and remove for ever the recreation and aesthetic qualities that had been enjoyed by many for so long.

A suit was filed against the County asking that King County Flood Control be enjoined from undertaking the "Miller Creek Flood Control Project" in a manner that would change the historical or present natural character or appearance of Miller Creek." A temporary restraining order was issued by Judge Callow in August, 1970. The trial has been continued 4 times and is now scheduled for trial in April 1974. Many violations of the injunction and its intent have been made.

Several studies of the watershed have been done through the years - for the airport - for the sewer district - and for King County and the State Highway. All agree that there will be a large amount of water to be coped with. In Jim Ames' report for the Fisheries Department he states "Perhaps the greatest value of Miller Creek as it now exists, is as an example of what not to do." He goes on to say that the destruction is due almost entirely to lack of total planning for man's activities in the water-shed. With proper direction, this would not have happened.

In the fall of 1972 RIBCO (River Basin Coordinating Committee) voted to use Miller Creek as a demonstration area for urban drainage problems and work out a program for alternate drainage methods.

It is hoped that solutions and drainage techniques can be found and implemented in time to save the uniqueness and natural resource of these streams.

LESSON 1

CONCEPT: Watersheds and their boundaries

MATERIALS: Pencil
grid paper
50' tape measure
straight edge
12" ruler
U. S. Geological survey maps - Des Moines quadrangle 7.5 minute series (one for each student)

INTRODUCTION: A watershed is an area of land from which all precipitation drains to a specific watercourse. The Columbia River, for example, is one of the largest watersheds in this country. However, this large system is made up of thousands of smaller ones which cover all types of terrain.

Each watershed, no matter how large or small it may be, has certain boundary lines. These boundary lines divide one drainage area from another. Ultimately, in watershed analysis and management one is faced with the need to identify these boundaries be they natural or man-made.

PURPOSE: To allow students to visualize a watershed and it's boundaries through personal observation, topographical map analysis and field survey procedures.

PROCEDURE: Although it is possible to convey the concept of a watershed as a drainage basin in the classroom a short exercise outside in constructing actual watershed boundaries may help clarify the student's conception.

1. Introduce the topic by simply initiating a short inquiry type discussion about the student's personal use of water.
Ask: *What is water used for in the home?*
Answers might include drinking, washing (people, dishes, clothes, etc.) sprinkling the lawn, etc.

NOTE: Make a list as the discussion continues. After five or six "uses" have been listed by the class,
Ask: *Which use they (the students) would discontinue first, then second and third, etc. if water was in short supply.*
Answers will logically progress from the less personal i.e. watering the grass, cleaning dishes to drinking (survival.)

2. The above discussion will help focus our dependence upon water to do a variety of services. The most important of which is survival. Stress this point.
Ask: *Can we (or any living thing) exist without water.*
Answer: No - sooner or later death is the eventual outcome.

Follow up by asking: *Since water is so important to us - shouldn't we know where it comes from? Where does our water come from?*

(NOTE: Avoid discussions on the Hydrologic Cycle by eliminating such things as the ocean, clouds, rain, etc. Try to direct response toward local water supplies.)

Answers should include local reservoirs, streams, creeks (in Burien, Miller Creek)

3. We're trying to narrow the topic down to a local (if not personal level.) To do this, we must become aware of local water sources. Similarily, we should become aware of where our water goes after we use it.
Ask: *Does anybody know where local (i.e. Burien) water goes after being used (in the manners previously discussed)?*

Answers might include (1) the ocean. OK, but how does it get there? (2) Soil - OK, but then where (3) Evaporates. Yes, but all of it? (4) Back into the stream channel

NOTE: Leave the discussion open, but eventually end up with the idea of local drainage by local stream(s) (i.e. Miller Creek for Burien)

4. Now that we have an idea where our water comes from (usually from local watercourses - i.e. Miller Creek in Burien) and where our water goes (usually back into this same watercourse) we can discuss water sources in different areas.

Ask: *What about people in Des Moines? Do they share the same water source as the people in Burien? Does their water drain into the same stream(s), etc.?*

Answer: Will depend on the student's knowledge of local watercourses. Direct class toward the idea of separate drainage systems. (Miller Creek - Burien, Des Moines Creek - Des Moines)

Stress to the students that:
1) different drainage systems are commonly known as watersheds.
2) each watershed has boundaries
3) these boundaries may be either man-made or natural

Topographical Map Analysis

PURPOSE: To chart the boundaries for the Miller and Des Moines drainage basins (watersheds) and to visually illustrate the area encompassed by each.

MATERIALS: U. S. Geological Survey Maps, Des Moines Quadrangle, 7.5 minute series (one for each student), dark pencil and pen.

PROCEDURE:
(1) Examine the map provided.
(2) Trace over (in pen) for easy identification Miller and Des Moines Creek and their tributaries.
(3) Draw in the boundaries of the watershed for each stream (with dark pencil). Boundaries should be estimated on the prerequisite that all surface runoff that occurs within the watershed will pass into the stream channel. (Remember water only flows down hill - check contour lines - elevations)

*See sample showing Miller and Des Moines Creek watershed boundaries. This is an example of what students should do on their USGS maps.

Field Survey

PURPOSE: This experiment will allow students to visualize watershed drainage patterns as well as provide a method for plotting drainage boundaries, calculating total watershed area (sq. ft.) and experimenting with different amounts of water runoff.

MATERIALS: Pencil, grid paper, straight edge, 50' tape measure and blue print of building if possible.

PROCEDURE:
(1) Have students visualize water draining off the roof, into the eavetroughs, into the downspouts and finally onto the ground. Each downspout has its own watershed. Now, what are the boundaries for each downspout (or watershed).
(2) Draw the outside foundation of the building to scale on your grid paper. Note the height and slope of the roof for each section of the building being used.
(3) Locate the downspouts of the eavetroughs on the perimeter of the building and indicate their location on your drawing.
(4) To calculate the area of the roof measure the length and width of the building involved.

NOTE: The area of the roof is viewed as a horizontal plane (see fig. #1)

Example #1

Suppose the length of your roof is 50' and the width is 24' (fig. #1)
NOTE: (Check blueprint if measurement is not possible)

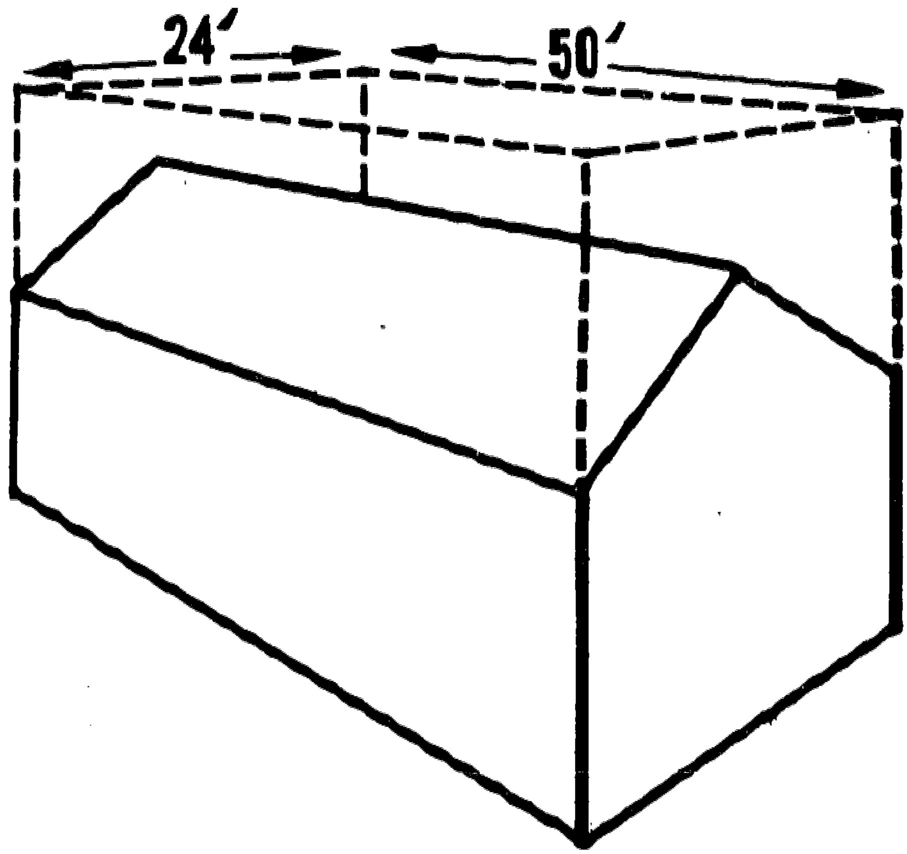
PROBLEM: How many gallons of water will come off a roof 50' long and 24' wide, when one inch of rain falls on that roof in 24 hours.

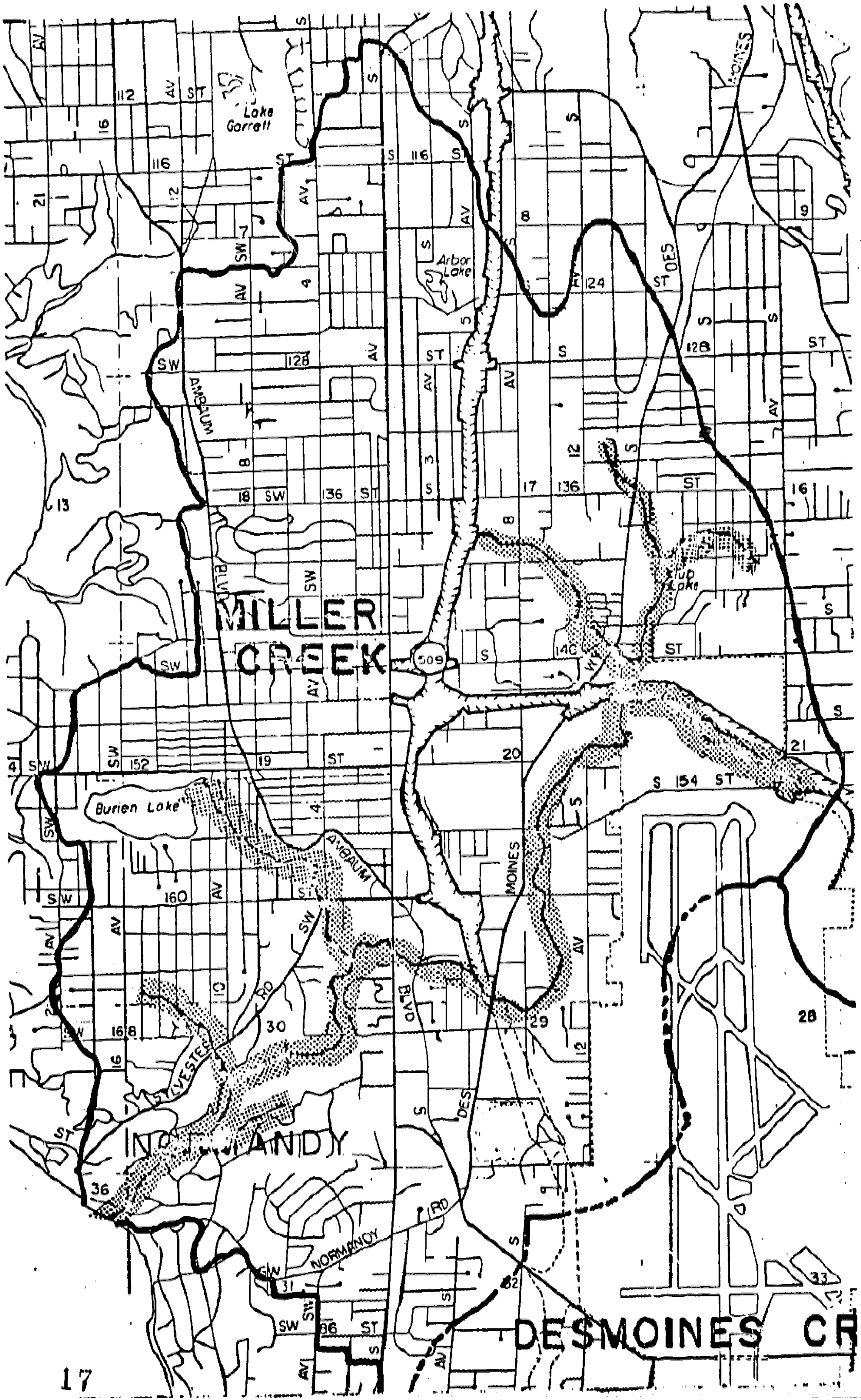
SOLUTION: Area of roof (horizontal plane)

50' x 24' = 1200 square feet
1" of water = 1/12 foot of water
1/12 foot x 1200 square ft. = 100 cu. ft.
1 cubic foot = 7.48 gallons
100 cubic feet = 748

fig. 1

# AREA OF ROOF
## (horizontal plane)




Lake Garrett
Arbor Lake
MILLER CREEK
509
Burien Lake
AMBAUM
SYLVESTER
NORMANDY RD
DESMOINES CR

LESSON 2

CONCEPT: The Hydrologic Cycle

MATERIALS: Materials for this lesson plan are listed with corresponding experiments.

TERMS FOR THE TEACHER:

1) Convection - a transfer of heat through movement of the air itself. Air heated by contact with a warm surface expands and becomes less dense. The lighter air thus created is replaced by cooler, heavier air from above and in turn forced upward.

2) Convergence - occurs when winds of different directions or speeds meet one another. Frontal lifting is a special type of convergence where two air masses of dissimilar temperature (etc.) collide.

3) Orographic Lifting - the ascension of air caused or intensified by any topographic obstruction on the earth's surface.

4) Condensation Nuclei - small particles present in the air on which condensation takes place.

5) Adiabatic Processes - temperature changes occuring without any heat being added to or subtracted from the air.

6) Nonadiabatic Processes - involve the gain or loss of heat by the air from or to an outside source.

7) Latent heat of Vaporization - the heat used in carrying out evaporation and retained by the water vapor (600 cal/gram of water at $0^0$ C)

8) Latent heat of Condensation - the heat given off in the process of condensation (600 cal/gr of water at $0^0$ C)

9) Dew Point - temperature at which air becomes saturated upon cooling and at which condensation normally begins.

INTRODUCTION: The basic hydrologic cycle consists of the evaporation of water from the ocean surface, the transport of water vapor over earth's surface, condensation, precipitation, and runoff back to the ocean. There are, however, many important factors that are essential to the regulation of this very important circulation.

(A) Two factors essential for the evaporative process are Energy and Water.
1) The primary controls on the rates of evaporation include: Temperature, Air Movement, and Air Moisture.

(B) Condensation results from a cooling process. The air is cooled to a point where its capacity to hold vapor is exceeded by the actual amount in the air.
1) The principal processes of cooling which produce condensation include: Convection, Convergence (of wind currents or air masses) and Orographic Lifting.

(C) Precipitation is water in liquid or solid form falling to the earth. It is always preceded by condensation (or sublimation - vapor to solid) Condensation and precipitation are dependent on condensation nuclei. Particles on which water droplets can coalesce.

PURPOSE: To introduce the student to the Hydrologic Cycle and to acquaint him (or her) with the various operating factors involved therein.

PROCEDURE: Although the student may be familiar with the generalized picture of the water cycle he is less likely aware of the workings within the cycle itself. Focus attention on each process: evaporation, condensation, precipitation by discovering the many intricasies of each.

EVAPORATION:
1) Begin by holding up a glass of water. Then "accidentally" spill it on (1) a student (or yourself) (2) a table (3) a radiator.
Ask: *What's happening in all three circumstances?* (Evidently, the water on the radiator is disappearing.) *Where's it going?*
Answers might include: (1) It's changing to a gas (2) It's running down the sides and onto the floor (perhaps - but not what we want) (3) It's evaporating.
Direct answers toward (1) and (3) above. Now have the students explain.
Ask: *So what's evaporation?*
Answer: It's a change from a liquid to a gas. (No deep dark secrets here. Just simply that. Agree and go on)

Let's look into evaporation a little deeper.
Ask: *What two things are necessary for evaporation to occur?*
Answers: temperature, heat, air (These are factors influencing the rate of evaporation but are not actually what we want here.
Ask: *What's present on the radiator, the table, or wherever else evaporation takes place.*
HINT: Let the students think they will tell you sooner or later.
Answer: water and energy.

We have concluded that energy is present when evaporation takes place.
Ask: *How is this energy used?* (Hint: go back to the idea of heat. Heat is energy - Right? Right). *Well, does evaporation consume or liberate heat.*

Answers: It consumes heat. (good guess?) Well, if you think that's the case - use an example. i.e. What about the basketball player who continually sweats during a hard game. This sweat evaporates and (1) cools or (2) heats up the player? Cools of course. Answer: Evaporation consumes heat and is a cooling process.

Since evaporation consumes heat
Ask: *Where does this heat (or energy) go?*
Let the students tell you
Answer: It's retained in the water vapor. The gas state.

NOTE: Now for the students information tell them that the amount of heat consumed by 1 gram of water at $0^0$ centigrade is approximately equal to 600 cal. Inform them that this is known as the Latent Heat of Vaporization.

The Rate of Evaporation is influenced by three major factors. We can discover these factors by setting up a small demonstration.

NOTE: The following experiment is probably best used as a demonstration for the entire class. The teacher may have one or two students set up the materials and do the manipulating necessary. It should be an entire class involvement however. Let the students decide what factors might influence the rate of evaporation and then test for visual proof. Make a list . Most (if not all) will fall under the three major categories listed in the experiment.

EXPERIMENT #1
Factors Influencing Evaporation

Materials - balance, single beam, center pivot, large sponge, plastic sandwich bag, strong light source
The teacher may wish to make this a single demonstration instead of a lab session.

Procedure:
1. Cut sponge into cubes of equal size and soak with water (keep soaking time equal). Squeeze until they no longer drip and then attach and balance (one on each arm)

2. Vary one factor at a time (leaving one sponge as control). Let students experiment, but be sure to cover:
   a. Air Temperature (heat with light source)
   b. Air Movement (fan air past sponge)
   c. Air Moisture (closed plastic bag)

NOTE: You may wish to alter 2 factors at the same time, later. This may allow the students to quantify the relative importance of each.

3. The best way to get an idea of the relative effect of each factor is to time how long it takes for the balance to shift.

4. Have students list factors and explain their conclusions: Let them name the three fundamental factors involved.

Condensation:

1. Begin by showing off the glass of ice water you prepared beforehand.
   Simply ask: *Why is there moisture on the outside of the glass?* (There should be)
   Answers might include:
   1. There's a leak (not likely)
   2. You wetted it (don't they trust you)
   3. The surrounding air (This is what we're looking for)

   OK, if they say it's from the surrounding air then you
   Ask - *Why isn't there water on everything else in the room?*
   (no answer) - Try this:
   Condensation (the change from water vapor to liquid water) is occuring only on the glass.
   Ask: *What's different about the glass?*
   Answers: 1) It's got water in it. (True, but what else)
   2) It's got ice in it (so what does that mean)
   3) It's colder

   The secret here is Temperature
   Ask: *Does anyone know how temperature relates to condensation?*
   Answer: None.
   Well try this.
   Ask: *What happens to air as it is cooled?*
   Answers: it sinks (in other words - it becomes more dense)
   Now ask: *As air becomes more dense it's capacity to hold water vapor (1) increases of (2) decreases?*
   Answer: decreases

   Summary: So that's it. Condensation results from a cooling process. Cooling lowers the capacity of the air to hold water vapor. When this capacity is reached or exceeded by further cooling the air is said to be saturated and condensation begins. This air will then be at its dew point temperature.

2. We have seen condensation in the classroom, but is there any visible proof that it actually occurs in nature?
   Ask the students.
   (Remember rain, snow, hail, etc. are forms of precipitation, not condensation)
   Answer: Clouds are our proof. They are the physical result of condensation.

NOTE: We know that condensation results from a cooling process. What then, causes air to cool in nature. Use of an example may be helpful here. Try this:

(Example: You're mountain climbing and as you progress upward towards the summit the temperature drops and you get colder and colder. Well air does the same thing. As it rises it gets colder and colder. So whatever causes air to rise will also cause it to cool.)

Ask the students if they can think of anything that may cause air to rise.

Answers (what we're looking for)
1) Mountains (landforms, etc.) This is known as Orographic lift. That is, air rising to move over a physical barrier.
2) Warm air rising. This is known as convection. Air as it is heated (by the sun-earth-etc.) has a tendency to rise.
3) The collision of two dissimilar air masses. One is warmer or colder than the other. Since cold air is more dense (heavier) the cold air mass will slip under the warm air mass forcing it higher. This is known as convergence.

EXTRA ACTIVITY: Adiabatic Rates

This activity gives the teacher a chance to reinforce some previously learned material and at the same time present new material in the form of a small written exercise.

1) Begin this activity by refering back to evaporation and the latent heat of vaporization.

Ask: *Evaporation is a __?__ process that __?__ heat.*
Answers: cooling, consumes
Ask: *Where does the heat go? __1__ Approximately how much is stored per gram of water at 0° centigrade? __2__ What is the name used to describe this stored energy (or heat)? __3__*
Answers: 1) Into the water vapor
2) 600 cal/gr at 0° centigrade
3) Latent heat of vaporization

2) Now discuss rising air. The students are aware (from our previous lesson) that rising air cools, but they probably don't know that this air cools at a constant rate.
Stress: 1) Air cools at the constant rate of 5.5° F for every 1000 ft. gain in elevation.
2) This is known as the Dry Adiabatic Rate

3) Now shift your emphasis to condensation.
Stress: 1) From our previous lesson we learned that rising, cooling air may condense.
2) Condensation is the opposite process of evaporation.

Ask: *What do you suppose happens in terms of air temperature and the Dry Adiabatic Rate when condensation occurs.*

Hint: If there is no response guide the students back to evaporation and the latent heat that was stored during the evaporative process.

Answers: 1) Air temperatures usually rise because the stored heat (600 cal/gr) is released.
2) The Dry Adiabatic Rate decreases to $3^{0}$ per 1000 ft. gain in elevation due to the same reason.

Stress: 1) Condensation is the opposite process of evaporation and releases approximately the same amount of energy as was stored during the evaporative phase.
2) This released energy (or heat) is known as the Latent Heat of Condensation.
3) During condensation the Dry Adiabatic Rate changes to a $3^{0}$ decrease for every 1000 ft. gain in elevation.
4) This new rate ($3^{0}$/1000 ft) is known as the Wet Adiabatic Rate.
5) Air may be heated Adiabatically as well as cooled. Subsiding air (moving downward) increases its temperature at $5.5^{0}$ per 1000' if condensation is not occuring.

Try the following quiz.

This diagram depicts a mountain range 6,000 ft. high, close to the ocean and lying at right angles to prevailing westerly winds. (This typifies the exact situation for Seattle (and vicinity) in relation to the Cascade Mountain range and the prevailing westerlies coming off the ocean.)

Imagine you're a parcel of air being forced inland by the westerly winds. You're elevation is approximately at sea level (and your temperature is $61^{0}$ F.) when you encounter the Cascades. What are you going to do? Rise upward. Exactly. This is known as __________ Lift. (Orographic)

1) Condensation begins at 2,000'. What is your temperature at this new height? ________F. ($50^{0}$)

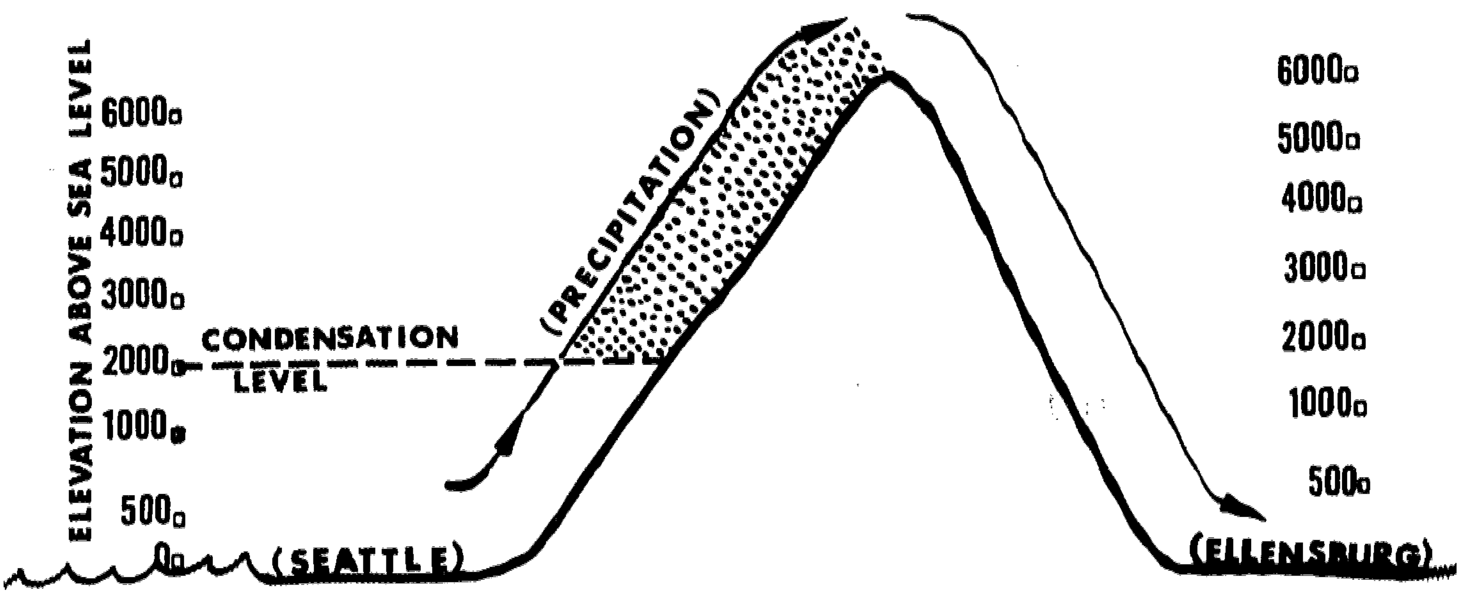
$$\begin{array}{r} 5.5^{0} \\ \times\ 2 \\ \hline 11.0 \end{array} \qquad \begin{array}{r} 61^{0} \\ -11^{0} \\ \hline 50^{0} \end{array}$$

When condensation begins the air is said to be __________ and at its ____________ ______________. (saturated, dew point)
Relative humidity is _____%. (100)

2) You continue to rise until you reach the summit at 6,000'. What is your temperature at this height? ______F (38)

$$\begin{array}{r} 3.0^{0} \\ \times\ 4 \\ \hline 12.0^{0} \end{array} \qquad \begin{array}{r} 50.0^{0} \\ -\ 12.0^{0} \\ \hline 38.0^{0} \end{array}$$

# ADIABATIC PROCESSES



What form of precipitation would you expect at this temperature? _____ (Rain)

3. The mountain barrier creates frictional drag as you cross the summit which forces you down the lee slope as indicated in the diagram. Your air mass is no longer saturated and condensation ceases as you begin your decent. You move downward until reaching sea level once more. What is your temperature? ______ $^{o}$F (71)

$$\begin{array}{r} 5.5 \\ \times\ 6 \\ \hline 33.0 \end{array} \qquad \begin{array}{r} 38^{o} \\ +33^{o} \\ \hline 71^{o} \end{array}$$

Is this the same temperature you recorded at this same elevation (sea level) before your assent (on the west side)? Why or why not? (A combination of Adiabatic processes (cooling and heating) and the release of Latent Heat (condensation).

A "Chinook" is a warm dry wind common in many parts of the Northwest. Could adiabatic factors be partially responsible for this interesting phenomenon? Discuss

- - - - - - - - - - - - - - - - - -

Precipitation:

1) Start out by asking: *What visible proof is there for this process?*
Answers: Rain, snow, hail, sleet, etc.
Ask: *What's the difference between precipitation and condensation?*
Answer: Look for something like precipitation is water (liquid of solid) falling to the earth whereas condensation is water suspended in air (i.e. clouds)

NOTE: Precipitation is <u>always</u> preceded by condensation, but condensation does <u>not always</u> result in precipitation.

2) Condensation and precipitation result from a combination of factors.
Ask: *Which factors have previously been discussed.*
Answer: Water and temperature

Stress: 1) Condensation requires the presence of one more factor and that is <u>condensation nuclei</u>.
2) These nuclei are tiny particulates suspended in the air. They provide the material upon which condensation takes place. Droplets of water coalesce (group together) on these nuclei until to heavy to be supported in air.

Ask: *Can you think of what these nuclei might be or where they come from?*
Answer: 1) salt, mostly from the ocean
2) insoluable dust particles
3) numerous chemical compounds from industry, etc.

NOTE: (Precipitation is a natural way of scrubbing the atmosphere clean. Air really is fresher after a rain.)

Experiment on Atmospheric Moisture:

Terms to know:

($H_r$) - Relative Humidity - the ratio of the amount of water vapor actually in the air to the amount the air could hold at a given temperature and pressure.

Using a sling psychrometer calculate the wet bulb and dry bulb temperatures for inside and outside the classroom. (You may want to vary this - for example the classroom and the greenhouse or the locker room, etc.)

The wet bulb depression is the difference between the dry bulb temperature and the wet bulb temperature (heat required to evaporate water from the wet bulb will cause it to show a lower temperature reading).

1. Consult Table I and determine the Dew Point Temperature
2. Consult Table II to determine the Relative Humidity.

TABLE I

TEMPERATURE OF DEW POINT ($F^{o}$)

From: Psychrometric Tables, U. S. Dept. of Commerce, Weather Bureau, W. B. No. 235, Marvin, C. F., 1941

DEPRESSION OF WET-BULB THERMOMETER (t-t')

| Air Temp. t | Vapor Press. "Hg(e) | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 0.046 | 3 | 2 | 1 | 0 | -1 | -3 | -4 | -5 | -7 | -8 | -10 | -12 | -14 | -16 | -19 | | | |
| 5 | 0.049 | 4 | 3 | 2 | 1 | 0 | -1 | -3 | -4 | -5 | -7 | -8 | -10 | -12 | -14 | -17 | | | |
| 6 | 0.052 | 5 | 4 | 3 | 2 | 1 | 0 | -1 | -3 | -4 | -5 | -7 | -8 | -10 | -12 | -14 | | | |
| 9 | 0.060 | 8 | 7 | 6 | 6 | 5 | 4 | 2 | 1 | 0 | -1 | -2 | -4 | -5 | -6 | -8 | | | |
| 12 | 0.070 | 11 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | -2 | -3 | | | |
| 13 | 0.073 | 12 | 12 | 11 | 10 | 9 | 8 | 8 | 7 | 6 | 5 | 4 | 2 | 1 | 0 | -1 | | | |
| 14 | 0.077 | 13 | 13 | 12 | 11 | 10 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | |
| 15 | 0.081 | 14 | 14 | 13 | 12 | 11 | 11 | 10 | 9 | 8 | 7 | 7 | 6 | 4 | 3 | 2 | | | |
| 17 | 0.089 | 16 | 16 | 15 | 14 | 14 | 13 | 12 | 11 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | | | |
| 18 | 0.093 | 17 | 17 | 16 | 15 | 15 | 14 | 13 | 13 | 12 | 11 | 10 | 10 | 9 | 9 | 7 | 6 | 5 | 4 |
| 19 | 0.098 | 18 | 18 | 17 | 16 | 16 | 15 | 14 | 14 | 13 | 12 | 12 | 11 | 10 | 9 | 8 | | | |

DEPRESSION OF WET-BULB THERMOMETER (t-t')

| Air Temp. t | Vapor Press. "Hg(e) | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 0.103 | 19 | 17 | 15 | 13 | 12 | 10 | 7 | 5 | 2 | -1 | -5 | -10 | -15 | -24 | -42 | | | |
| 23 | 0.118 | 22 | 20 | 19 | 17 | 15 | 13 | 12 | 10 | 7 | 5 | 1 | -2 | -6 | -11 | -17 | -27 | | |
| 24 | 0.124 | 23 | 21 | 20 | 18 | 17 | 15 | 13 | 11 | 9 | 6 | 3 | 0 | -3 | -7 | -13 | -20 | | |
| 25 | 0.130 | 24 | 22 | 21 | 20 | 18 | 16 | 14 | 12 | 10 | 8 | 5 | 2 | -1 | -5 | -9 | -15 | | |
| 27 | 0.143 | 26 | 25 | 23 | 22 | 20 | 19 | 17 | 15 | 13 | 11 | 9 | 7 | 4 | 0 | -4 | -8 | | |
| 29 | 0.157 | 28 | 27 | 25 | 24 | 23 | 21 | 20 | 18 | 16 | 14 | 12 | 10 | 8 | 5 | 2 | -2 | | |
| 31 | 0.172 | 30 | 29 | 28 | 26 | 25 | 24 | 22 | 21 | 19 | 17 | 16 | 14 | 11 | 9 | 7 | 3 | | |
| 32 | 0.180 | 31 | 30 | 29 | 27 | 26 | 25 | 23 | 22 | 20 | 19 | 17 | 15 | 13 | 11 | 9 | 6 | | |
| 34 | 0.195 | 33 | 32 | 31 | 30 | 28 | 27 | 26 | 25 | 23 | 22 | 20 | 18 | 16 | 14 | 12 | 10 | | |
| 35 | 0.203 | 34 | 33 | 32 | 31 | 30 | 28 | 27 | 26 | 24 | 23 | 21 | 20 | 18 | 16 | 14 | 12 | | |
| 36 | 0.211 | 35 | 34 | 33 | 32 | 31 | 29 | 28 | 27 | 26 | 24 | 23 | 21 | 20 | 18 | 16 | 14 | | |
| 41 | 0.256 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 32 | 31 | 30 | 29 | 28 | 26 | 25 | 24 | 22 | | |
| 42 | 0.266 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 32 | 31 | 30 | 29 | 28 | 26 | 25 | 24 | | |
| 44 | 0.287 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 32 | 31 | 30 | 29 | 27 | 26 | | |
| 46 | 0.310 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 32 | 31 | 30 | 29 | | |
| 51 | 0.373 | 50 | 49 | 48 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 38 | 37 | 36 | 35 | 34 | 32 |
| 52 | 0.387 | 51 | 50 | 49 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 36 | | |
| [illegible] | [illegible].417 | 53 | 52 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | | |

TABLE II
RELATIVE HUMIDITY (%)

From: Psychrometric Tables, U. S. Dept. of Commerce, Weather Bureau, B. B. No. 235, Marvin, C. F., 1941

| Air | DEPRESSION OF WET BULB THERMOMETER (t-t') | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 |
| 14 | 97 | 93 | 90 | 87 | 83 | 80 | 77 | 74 | 70 | 67 | 64 | 60 | 57 | 54 | 51 | 48 | 45 | 41 | 38 | 35 |
| 15 | 97 | 93 | 90 | 87 | 84 | 81 | 78 | 75 | 71 | 68 | 65 | 62 | 59 | 56 | 53 | 50 | 47 | 44 | 40 | 37 |
| 17 | 97 | 94 | 91 | 88 | 85 | 82 | 79 | 76 | 74 | 71 | 68 | 65 | 62 | 59 | 56 | 53 | 50 | 47 | 45 | 42 |
| 18 | 97 | 94 | 91 | 89 | 86 | 83 | 80 | 77 | 74 | 72 | 69 | 66 | 63 | 60 | 58 | 55 | 52 | 49 | 47 | 44 |
| 19 | 97 | 94 | 92 | 89 | 86 | 83 | 80 | 78 | 75 | 72 | 70 | 67 | 64 | 62 | 59 | 56 | 54 | 51 | 48 | 46 |

| Air | DEPRESSION OF WET BULB THERMOMETER (t-t') | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 |
| 23 | 94 | 88 | 82 | 76 | 70 | 64 | 58 | 52 | 46 | 40 | 35 | 29 | 24 | 18 | 13 | 7 | 2 | | | |
| 24 | 94 | 88 | 82 | 76 | 71 | 65 | 59 | 53 | 48 | 42 | 37 | 31 | 26 | 21 | 15 | 10 | 5 | | | |
| 25 | 94 | 88 | 83 | 77 | 71 | 66 | 60 | 55 | 49 | 44 | 38 | 33 | 28 | 23 | 18 | 13 | 8 | 3 | | |
| 31 | 95 | 90 | 85 | 81 | 76 | 71 | 67 | 62 | 57 | 53 | 48 | 44 | 39 | 35 | 31 | 26 | 22 | 18 | 14 | 10 |
| 32 | 95 | 90 | 86 | 81 | 77 | 72 | 68 | 63 | 58 | 54 | 50 | 45 | 41 | 37 | 33 | 28 | 24 | 20 | 16 | 12 |
| 34 | 95 | 91 | 87 | 83 | 79 | 74 | 70 | 65 | 61 | 57 | 53 | 49 | 45 | 41 | 36 | 32 | 29 | 35 | 21 | 17 |
| 35 | 96 | 92 | 87 | 83 | 79 | 75 | 71 | 67 | 62 | 58 | 54 | 50 | 46 | 42 | 38 | 34 | 31 | 27 | 23 | 19 |
| 36 | 96 | 92 | 88 | 84 | 80 | 76 | 72 | 68 | 64 | 60 | 56 | 52 | 48 | 44 | 40 | 36 | 33 | 29 | 25 | 21 |
| 41 | 96 | 93 | 89 | 85 | 82 | 79 | 75 | 71 | 68 | 64 | 61 | 58 | 54 | 51 | 48 | 45 | 41 | 38 | 35 | 31 |
| 42 | 96 | 93 | 89 | 83 | 82 | 79 | 75 | 72 | 68 | 65 | 62 | 59 | 55 | 52 | 49 | 46 | 42 | 39 | 36 | 33 |
| 46 | 97 | 93 | 90 | 87 | 84 | 81 | 77 | 74 | 71 | 68 | 65 | 62 | 59 | 56 | 53 | 50 | 47 | 44 | 41 | 38 |
| 51 | 97 | 93 | 91 | 88 | 85 | 82 | 79 | 76 | 73 | 71 | 68 | 65 | 62 | 60 | 57 | 54 | 52 | 49 | 47 | 44 |
| 52 | 97 | 94 | 91 | 88 | 85 | 83 | 80 | 77 | 74 | 71 | 68 | 66 | 63 | 60 | 58 | 55 | 53 | 50 | 48 | 45 |
| 54 | 97 | 94 | 91 | 88 | 86 | 83 | 80 | 77 | 75 | 72 | 69 | 67 | 64 | 62 | 59 | 57 | 54 | 52 | 49 | 47 |

# LESSON 3

CONCEPT: Runoff; how it is generated by a watershed.

MATERIALS: materials are listed with experiment

INTRODUCTION: Precipitation is the source for all runoff. However, this runoff reaches the stream channel by four primary routes. These include:

1) Channel Interception - precipitation that falls directly into the stream channel

2) Surface Runoff - (overland flow) - That portion of precipitation which does not infiltrate into the soil but flows over the surface until it reaches a channel.

3) Sub-Surface Storm Flow (interflow) - precipitation that infiltrates into the soil, but is diverted laterally by a layer of restricted permeability (hardpan, bedrock) until reaching a channel.

4) Base Flow - portion of precipitation which percolates deep and is released slowly through time.

PURPOSE: To introduce the student to runoff and the primary routes by which it reaches the stream channel. Also, to graphically illustrate, by hydrograph analysis, the effect of each route after a storm.

PROCEDURE: 1) This lesson begins where the previous one left off. That is with precipitation.

Precipitation is usually* incorporated into a stream channel. Ask: *Can you think of any ways in which water reaches a stream channel?*

NOTE: Make a list. If you give them enough time they should come up with all four primary routes. Any ideas should fall under one of these.

Answers: 1) Channel Interception - precipitation falling directly into the channel.

2) Surface Runoff - precipitation that flows over the surface and into a channel

* Some precipitation is evaporated back into the air before reaching a stream channel. Similarily, some water is absorbed and transpired into the atmosphere by plants. The combination of this water loss back to the atmosphere is known as evapotranspiration.

3) Sub-Surface Storm Flow - precipitation that infiltrates the soil, but is diverted laterally be restricted permeability until reaching a channel.

4) Base Flow - portion of precipitation which percolates deep into the soil and is released slowly through time.

2. Hydrographs are graphs on which stream flow is plotted as a function of time. These graphs are useful devices for studying the effects of storms on flooding. With the use of hydrographs accurate forcasts of stream discharge are possible. Such forcasts are based primarily upon the knowledge of flow patterns.

a. For example: If we set up a monitor on Miller Creek to graph the streamflow before, during, and after a large storm we would see some predicable changes on our hydrograph.

Ask: *Which of the four primary routes (previously discussed) would most likely supply the water which shows up first on our hydrograph.*
Answer: Channel Interception
Ask: *Why?*
Answer: Because it is incorporated directly into the channel (little to impede its movement out of the watershed)

Show transparency. This is a typical graph denoting water received by Channel Interception.

1) Note it's relation to the storm and it's quick, but restricted "jump"

2) Ask the students why this graph appears as it does?
i.e. 1) Why not greater in height (volume)
2) Why is there no time lag* at the beginning of the storm?
3) Why is there a short time lag at the end of the storm.

Answers:
1) Volume is restricted due to the small amount of surface area encompassed by the stream channel in relation to the total watershed.
2) There is no time lag at the beginning of the storm because water is incorporated directly into the stream at monitoring station.

*Time Lag - The time interval between the beginning (or ending) of precipitation and the beginning (or ending) of this "new" water as shown on the hydrograph.

3) Time lag at end depends on rate at which water in upper portions of channel is transported (past hydrograph) and out of watershed

Considering the three remaining routes we have to cover
Ask: *Which would be most likely to show up (next) on our graph. (following Channel Interception)*
Answer: Surface runoff
Ask: *Why?*
Answer: Simply because it has less to impede its journey to the stream channel.

Water that runs off over the earth's surface can vary significantly from watershed to watershed.

Ask: *Can you think of any reason why Surface Runoff might be greater on one watershed than on another?*
Answer: It's the amount of impermeable surface and/or precipitation excess.*

For a good example of what we mean here, try this experiment.

CALCULATION OF SURFACE RUNOFF

PURPOSE: To compare the relative amounts of SRO that can be expected from two different areas within the city.

MATERIALS: Pencil, paper, 50' measuring tape

PROCEDURE: You are to determine the percent of surface runoff that can be expected from two city blocks (or any two areas of similar size) in (1) a downtown area (i.e. parking lot, etc.) and in (2) a residential section (park, etc.)

1) Assume that all the rainfall that reaches the ground continues on downward into the soil and that any that lands on rooftops, or other hard surfaces (asphalt, concrete, driveways, sidewalks, etc.) occurs as SRO.

2) Calculate the area of block in square ft.

3) Calculate the hard surfaced area occuring within each block (include area covered by buildings) in square feet.

4) Calculate the % of RO as

$$\% \text{ Runoff} = \frac{\text{Area of hard surface}}{\text{Total area of block}} \times 100\%$$

Do this for each block (or several) and compare.
NOTE: Natural areas average approximately 30% for nation as a whole

* Precipitation Excess - precipitation that cannot be incorporated into the soil. Usually because soil capacity has been exceeded.

Now look at the transparency depicting Surface Runoff. Lead the discussion into the following:

1) How does this graph compare with the previous one on Channel Interception?
2) Why is there a time lag between the beginning of the storm and peak Surface Runoff (SRO) flow?
3) What factors might influence this lag.

Answers to discussion:

1) At the beginning of the storm the hydrograph rises slowly at first because water from only a small part of the watershed reaches the channel. Then more rapidly as water from greater distances appear.

   The volume is much larger than CI (Channel Interception) because SRO draws from the total watershed area whereas CI is restricted to the channel itself.

2) Some SRO appears on the hydrograph <u>almost</u> immediately as areas nearby begin to drain. There is a slight delay, however, as SRO is always impeded in its journey by overland travel.

3) The factors influencing the amount of time lag are
   a) The rate of flow over the surface.
   b) The distance which it must flow before it reaches the channel.
   c) The distance and rate of channel flow before it passes hydrograph and leaves the watershed.

3. Sub-Surface Storm Flow is that water which percolates into the soil and seeps laterally until reaching the stream channel.

   Ask: *What do you suppose the hydrograph looks like for this portion of streamflow?*

   NOTE: Have the students try and construct a graph depicting sub-surface storm flow on the board.

   CONSIDER: 1) Will it show up as soon as CI and SRO
   2) Will discharge be as great as SRO.
   3) What about time lag? Will it take a shorter, longer or equal amount of time to drain out of the watershed.

   After doing a graph to the student's satisfaction, show transparency for Sub-SSF.

   Discussion: Note that sub-surface storm flow increases slowly on the hydrograph because of the tortuous route it follows and the great frictional resistance it must overcome as it moves through the soil. Its volume is usually <u>below</u> that of SRO

because the storage capacity of the soil for water is restrictive. When the rate at which water can infiltrate into the soil is exceeded the surplus moisture drains as SRO. Similarily, if the water storage capacity of the soil is exceeded, then surplus again drains as SRO.

Sub-surface storm flow does not appear until SRO recedes. The time lag following the storm is lengthy and continues, sometimes for days, after the storm.

4. There is no sharp distinction between sub-surface storm flow and base flow.

Show transparency

Perhaps the only real distinction that can be made is in terms of the time period over which flow to the channel continues after precipitation stops.

STRESS:
1. Sub-Surface Storm Flow can usually be identified as due to a given storm.
2. Base flow cannot
3. Base flow continues in slowly decreasing amounts over a long period of time. It is released so slowly that it may represent water from many different storms. It does not appear until streamflow has receded to nearly pre-storm level.

FINAL DISCUSSION:

1) Show composite transparency showing various sources of runoff in relation to total streamflow.
2) Discuss how analysis of each flow might provide valid information for forcasting total stream discharge.

ANSWER: With a comparison of similar hydrographs collected through time we can have excellent predictions on the seriousness of storm flow. Comparison of individual graphs may provide the necessary information to predict floods, flood levels, and possible damage extent. Reports of measured flow from upstream locations are collected to determine the amount of water that can be expected to pass specific points downstream.

EXTRA ACTIVITY:

1. Construct a glass model showing primary RO routes and a description of each.
2. Lab exercise on hydrograph analysis. (See ditto)

LABORATORY EXERCISE # 7

Hydrograph Analysis

**Purpose:** To construct an analysize a hydrograph (done in conjunction with visit to sewerage plant)

**Introduction:** A hydrograph is a graphical representation of changes in stream level (or other flowing source of water such as a storm sewer or water main) presented in chronological order. There are numerous values that can be extracted from a hydrograph through an analysis procedure. These values can then be used to study the influence of storm patterns, storm intensities, storm sizes, etc. on existing watersheds, or they may be used to evaluate the effect of different vegetational types, or ground cover (such as a new shopping center on an empty lot or the addition of a new apartment complex to a sewer system). They can be used to determine the size and capacity, needed to adequately handle a volume of water, be it surface runoff in storm sewers or domestic waste in normal sewer lines.

The ten most commonly used values are:

1. $t_1$ = time of day that event begins (storm, heavy use of showers)
2. $t_p$ = time to peaking of hydrograph (elasped time between the start of the event and maximum flow or use)
3. $t_{d_1}$ = quick flow duration (elasped time from beginning of event to end of major portion of use)
4. $t_{d_2}$ = Flow duration from end of quick flow to the beginning of the next event
5. $q_1$ = intial flow rate in cubic feet per minute (rate of flow before event began)
6. $q_p$ = peak rate of quick flow in cubic feet per minute (rate of flow at greatest volume per minute)
7. $q_f$ - rate of flow at end of quick flow in cubic feet per minute (rate of flow at the end of $t_{d_1}$)
8. v = volume of quick flow in cubic feet or gallons or acre feet
9. $a_1$ = volume of delayed flow for the duration of quick flow in cubic feet, gallons, or acre feet (represents volume that would have normally occured had not the event taken place)
10. $a_2$ = volume of delayed flow from the end of quick flow to the beginning of the next event in cubic feet, gallons, or acre feet.

**Procedure:**

1. You are to record the rate of flow in cubic feet per minute of sewerage entering the treatment plant three times a day for five consecutive days. Record this data in Table I.

2. On a piece of graph paper plot the rate of flow versus time, with flow in cubic feet per minute on the y-axis and time in hours on the x-axis.

3. Determine the values of the ten factors listed under Table I.

4. Repeat steps 1-3 using data gathered during a five day period in which rain occured.

5. Compare the two graphs, what would you expect them to look like if:

a. the ground had been frozen during the rain.
b. no rain had occurred for the past six months.
c. instead of rain the precipitation had occurred as snow which then melted over a long period of time.

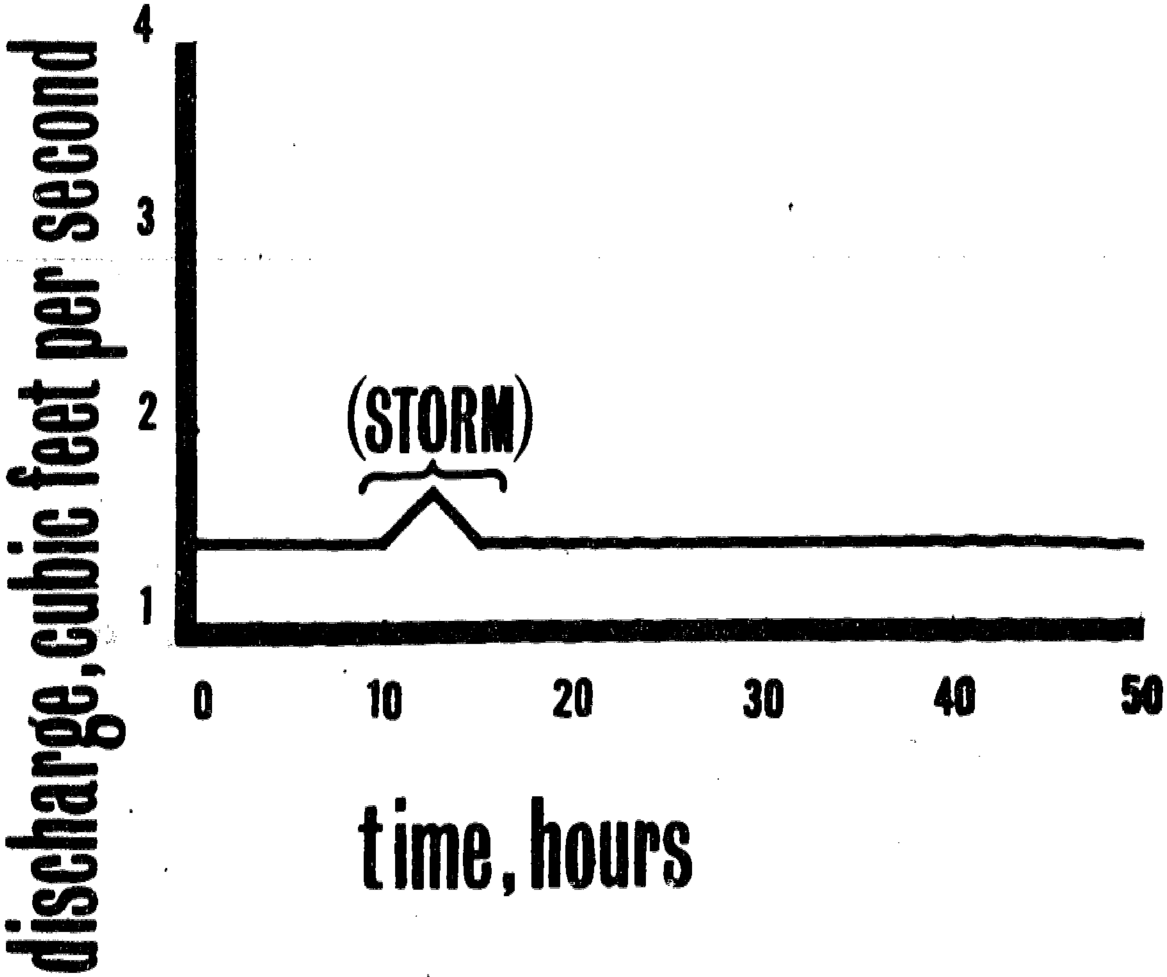
TABLE I

| TIME | NORMAL FLOW (cubic feet per minute) | | | | RAIN | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | DAY 1 | DAY 2 | DAY 4 | DAY 5 | DAY 1 | DAY 2 | DAY 3 | DAY 4 | DAY 5 |
| 9:00 A.M. | | | | | | | | | |
| 12:00 noon | | | | | | | | | |
| 3:00 P.M. | | | | | | | | | |

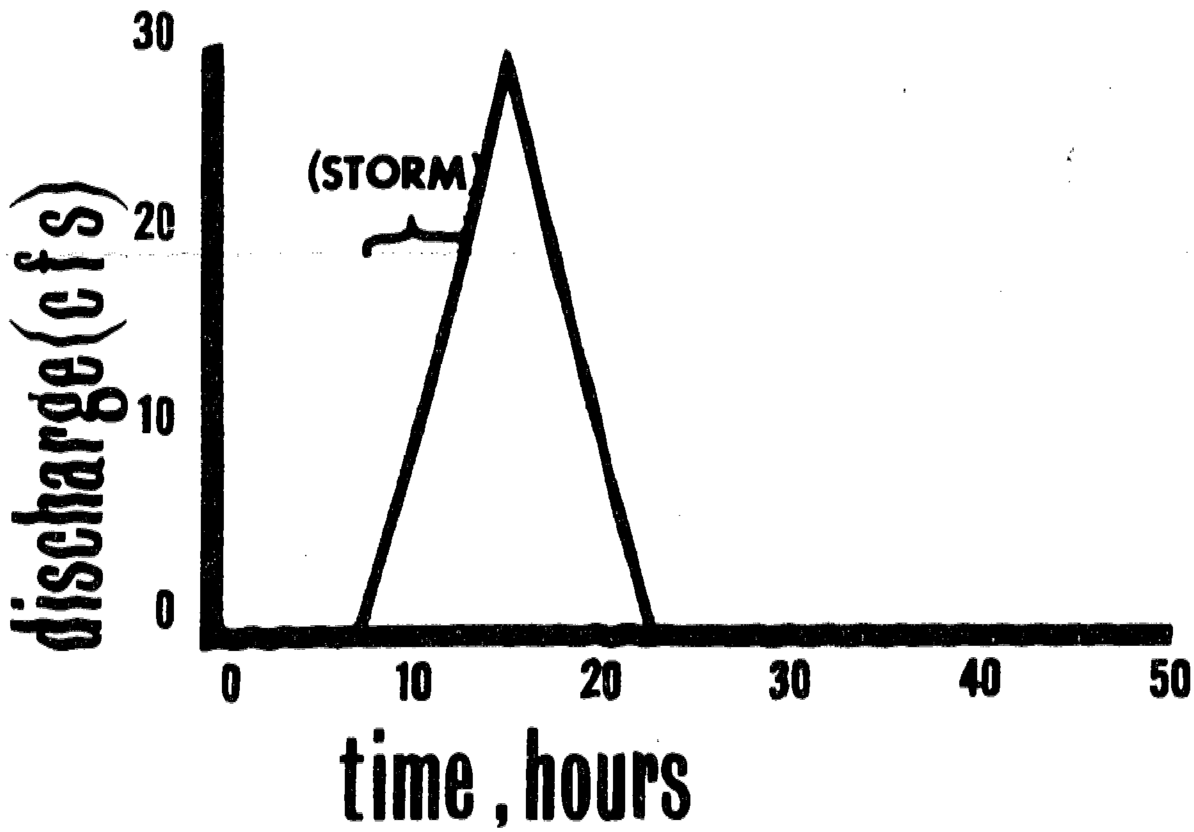
| | NORMAL | RAIN | | NORMAL | RAIN |
|---|---|---|---|---|---|
| 1. $t_1$ = | | | 6. $q_p$ = | | |
| 2. $t_p$ = | | | 7. $q_f$ = | | |
| 3. $t_{d_1}$ = | | | 8. v = | | |
| 4. $t_{d_2}$ = | | | 9. $a_1$ = | | |
| 5. $q_1$ = | | | 10. $a_2$ = | | |

Note: The data needed for this exercise may be collected in advance by the instructor to facilitate this lesson, although this action may diminish the effectiveness of the activity. A hypothetical hydrograph is given on the following page with the parameters to be studied indicated.

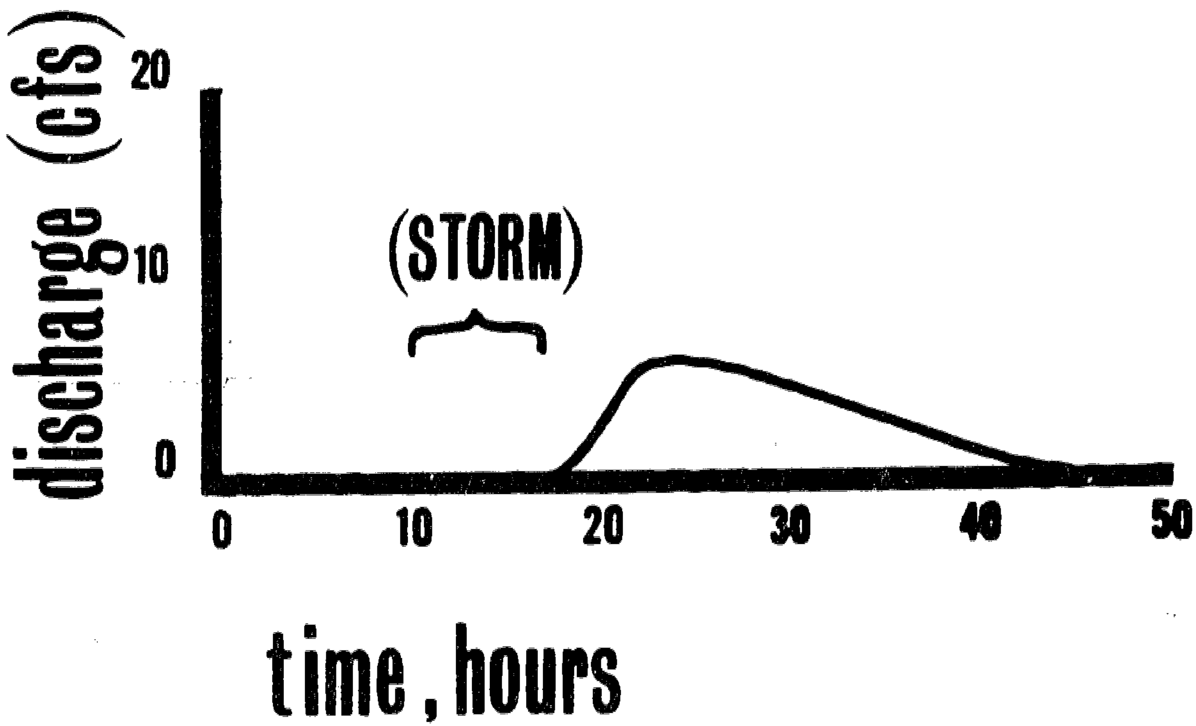
# CHANNEL INTERCEPTION:



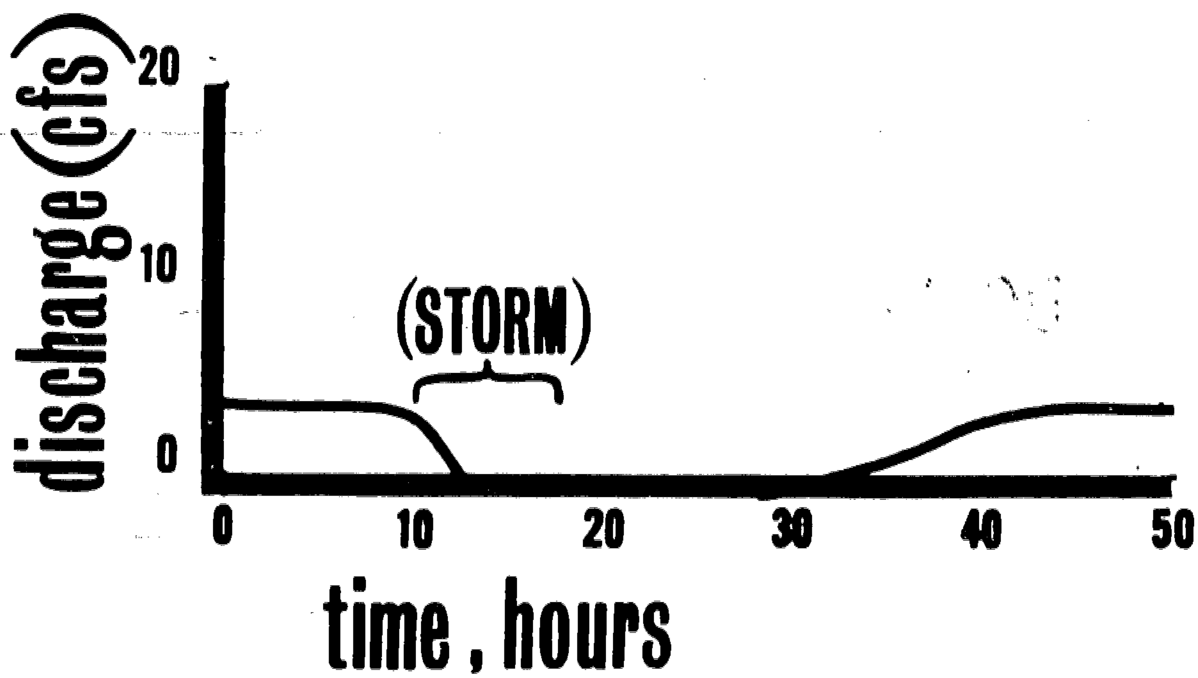
# SURFACE RUNOFF:



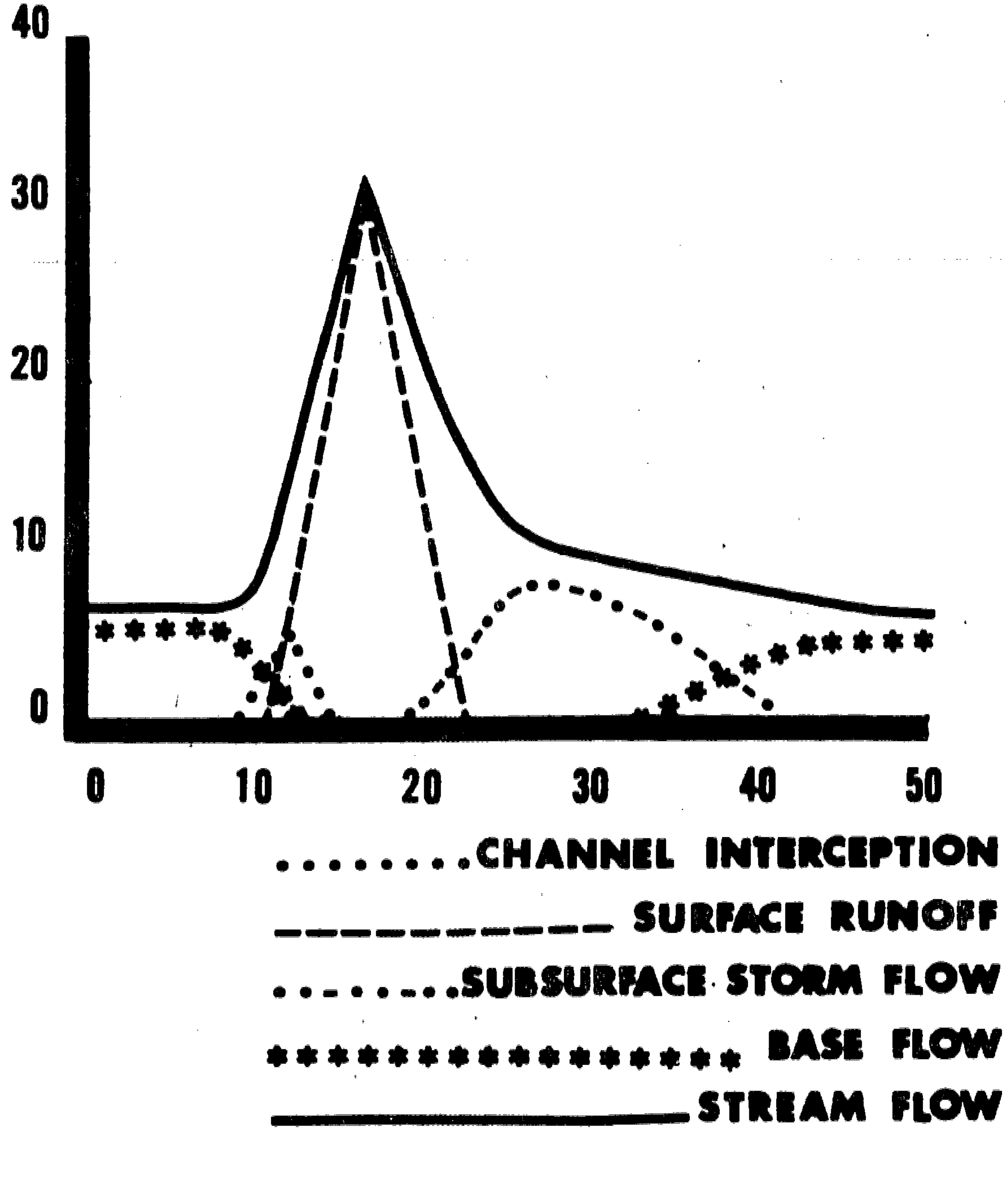
# SUBSURFACE STORM FLOW:



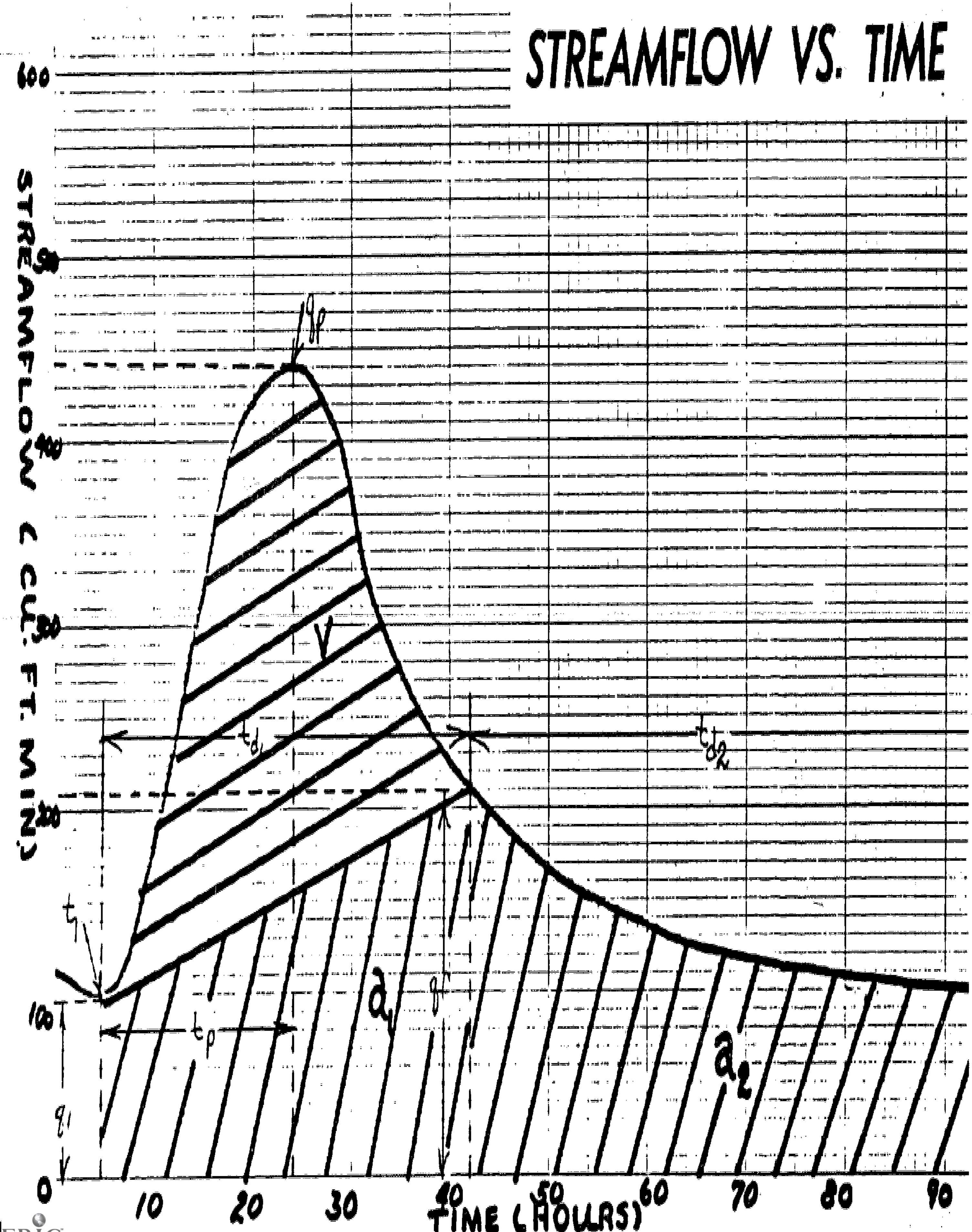
# BASE FLOW:



# COMBINATION GRAPH:



# STREAMFLOW VS. TIME



CONCEPT: Infiltration and storage of water in the soil profile

MATERIALS: Listed by experiment

INTRODUCTION: The path followed by precipitation in its journey from the point of impact on the watershed until it is discharged into the stream channel is a very interesting and sometimes very lengthy process.

Part I - INFILTRATION is the process by which water enters and moves through a watershed surface. In general there are two groups of factors which control infiltration rates. These include:

a) factors which determine how rapidly the surface can absorb $H_2O$ (determines Infiltration Capacity)

b) factors which determine the rate at which $H_2O$ is applied to the surface. (Infiltration rate is either less than or equal to the infiltration capacity.)

The factors most suitable for modification by man are those controlling infiltration capacity. These include:

a) Soil texture (individual particle size)
b) Soil Structure (the arrangement of soil particles in aggregates)
c) Nature of Soil Colloids (some colloidal materials swell upon wetting. Others do not)
d) Soil Moisture Content (The amount of moisture already in the soil.)

Although these factors influence the infiltration rate, there are two driving forces that are essential to water movement:

a) Gravity - a constant force acting on individual water molecules
b) Capillary - a variable force depending on the previously mentioned factors.

PURPOSE: To acquaint the students with the two main water driving forces in the soil and to show through discussion and experimentation the major factors influencing infiltration capacity.

PROCEDURE: (Part I) To understand how water enters the soil begin with a short example: i.e. When we exert ourselves in any physical activity we notice beads of sweat on our skin. These beads of sweat flow from tiny pores (stress pores) which cover our body.

Similarly, spaces or pores between soil particles allow water to seep downward into the earth's surface.

Stop. Ask: *But have you ever wondered why water seeps downward? What force(s) act on water to move in into and through the soil structure?*

Answers: The first force is Gravity. (Students will probably get this one right away. Find out what they know about it.) Ask: *In what direction does gravity act? Is gravity a constant force?* Answers: Gravity is a unidirectional force which pulls downward at

all times. Gravity is a constant force, but when water depth is greater than one molecule thickness this force is cumulative in nature. Each layer adds that much more weight.

The second force is usually not as easy. A brief example may help clarify Capillary Force.

1) Let water run into and out of a pipette. Show it to the class.
2) Ask: *What keeps this last drop of water from running out?*
   Answer: It's our second force. That is, Capillary Force.

Capillary force works on and in the soil like gravity, but it differs somewhat.

STRESS:

| Capillary | Gravity |
|---|---|
| 1. Independent of direction (up, down or sideways) | 1. Unidirectional (always downward) |
| 2. Variable force depending on (a) size of soil pores (b) the physical attraction of soil particles for water (c) the moisture content of the soil | 2. Constant, but cumulative per layer |

Now that we know what drives water into the soil find out what influences the Infiltration Capacity* of the soil.

Try the following experiment. NOTE: If this experiment is not possible an alternative experiment can be found in the teacher's guide (Part I) Investigating the Earth (ESCP) Chapter 9, page 258 (Investigating the movement of water in earth)

MEASUREMENT OF AND FACTORS INFLUENCING INFILTRATION

PURPOSE: To identify four primary factors which effect the rate of infiltration of water into the soil.

MATERIALS: Three types of soil that have been oven dried (all moisture removed), funnels, filter paper, water, beakers, pencil and paper.

PROCEDURE: Divide class into groups according to the amount of equipment available.

*Infiltration Capacity - rate at which water can infiltrate into the soil. Actual infiltration rate is either less than or equal to this infiltration capacity.

1) Each group of students will be given three spearate jars of soil.
   a) clay - which has very small particles
   b) loam - which has medium sized particles
   c) sand - which has the largest sized particles

2) Line each funnel with filter paper and fill it about half full of one type of soil (do not pack soil) - 3 funnels three types of soil

3) Place each funnel over an empty beaker and pour an equal volume of water into each of the three funnels. Record the time it takes between the addition of the water and the first drop falling into the beaker below. Put this data in Column #1 on table provided.

4) Repeat steps 1-3, this time packing the soil in the funnel before adding the water. Record the elapsed time in Column #2.

5) Repeat steps 1-3, this time saturate the soil with water before determining the rate of infiltration. This may be done by adding water to the funnels used in the first step and letting them stand until water no longer drips from funnel. Record data.

| Soil Type | Time Dry (sec) | Time Satur. (sec) | Time Packed (sec) |
|---|---|---|---|
| Clay | | | |
| Loam | | | |
| Sand | | | |

What are the four factors you feel effected the rate of infiltration, as indicated by this exercise. Let them tell you. Don't give up (help them with hints if needed), but eventually they should come up with the following:

1. Soil Texture (individual particle size)
2. Soil Structure (the arrangement of soil particles in aggregate)
3. Nature of Soil Colloids
4. Soil Moisture Content

Ask: *One more question. Do you think Infiltration capacity can change through time? But how?*

Answer: Infiltration capacity may change due to a variety of reasons.
1) compaction: As soil is compacted (by animal or man) pores are closed and the surface becomes almost impermeable.
2) swelling of colloids: Some soils have a tendency to swell when wet. This expansion causes closure of pore spaces and thereby decreasing infiltration capacity.
3) Air entrapment: Water moving into pores may trap air below stopping normal flow. (i.e. gas in the stomach)

Part II

INTRODUCTION:
1. Storage - Water infiltrating through the surface is either stored in the mantle or continues to move through the soil. The major forces causing storage and movement are the same as those acting on infiltration namely: Gravity and Capillarity. Capillarity however may act to prevent small pores from emptying as well as induce further movement into unfilled pores.

If the soil is occupied with plant roofs a third force absorption comes into play.

Thus for a time after a dry soil has been wetted water may be
1) Moving out of profile into plant roots
2) Moving into the air by evaporation
3) Downward and/or laterally by gravity and/or capillary

From this we may conclude that pore size and volume are the major determinants in water movement and storage in the soil.

2. Two important types of soil moisture are:
a) Gravitational $H_2O$ - water which moves freely through the soil in response to gravity.
b) Capillary water - water which is retained in soil pores by molecular attraction against gravity

PROCEDURE: 1. From our previous work on infiltration we recognized two major forces inducing water movement into the soil. They are (1) Gravity, (2) Capillary.

a) These same two forces act on water storage as well. Gravity, for example, affects storage in two entirely different ways. These include:

STRESS: 1. Gravity fills pore spaces by exerting a constant downward force on surface water.
2. This same downward force tends to force water down through the soil draining upper pores as it goes.
3. It is evident that gravity exhibits a positive "filling" force as well as a negative "draining" force on water storage.

b) Capillary shares this same dicotomy. That is, it induces (pos) as well as drains (neg) soil moisture.

STRESS: Unlike gravity, however, capillary force is variable and most dependent on one particular factor.
Ask: *Does anyone know what this factor is?*
Answer: pore size.

HINT: There may be difficulty here either in obtaining an answer or understanding the answer given. To help clarify the idea of capillary force and pore size bring out a pipette and procede with the following visual example.

1. Allow some water to drain through the pipette.

2. Assume that the larger portion is a particular soil pore size. Similarily, assume that the smaller tip portion is another soil pore size.

3. Ask: *Why does the last drop of water that runs from the larger pore stop and remain on the neck of the smaller pore.*
   Answer: The capillary force is greater here than in the larger pore (above).

NOTE: This is similar to what happens in the soil.

Ask: *Why do larger pores drain first?*
Answer: Because the capillary retention force* in the large pores is not sufficient to resist the combined downward forces of gravity and capillary.

c. There remains one force other than gravity and capillary that may effect storage of water in the soil.

STRESS: This force is known as absorption.

Ask: *What do you think causes this force to exist.*
Answer: Plants

Discussion: 1) Plant absorption may come in direct conflict with capillary retention force.
Ask: *Does anybody know why? Does anybody know what occurs when this conflict comes into equilibrium (both forces are equal)*
Answer: (what we're eventually looking for) - Part of the moisture in the soil is held at tensions less than those that can be exerted by the roots of the plants, and can therefore be withdrawn by them. However, as water is withdrawn from the larger capillary pores, the remaining water is retained even more strongly. Ultimately, the force that can be exerted by plant roots comes into equilibrium with that of the soil and further plant withdrawal virtually ceases. The plants then wilt. The moisture content at this point is termed the permanent wilting point. From our previous discussion it should be clear that two things are major determinants of water storage and movement.
Ask: *Can you name them?*
Answers: (1) Gravity (2) Capillary

*Capillary Retention Force - the "positive" restraining force that retains water in soil pores thereby not allowing it to drain further downward.

These two, particularly capillary, are in turn influenced by two other factors.
Ask: *Can you name them?*
Answer: Pore size and volume are what we're after here.

EXPERIMENT AND/OR EXTRA ACTIVITY: Construction of the Hydrologic Cycle as it functions within a typical city.

PURPOSE: To allow the student to use the previous information gathered in lessons 1-4 and to construct a diagramatical sketch including as many segments of hydrologic cycle as possible.

MATERIALS: Pencil, paper, eraser, and possible straight edge

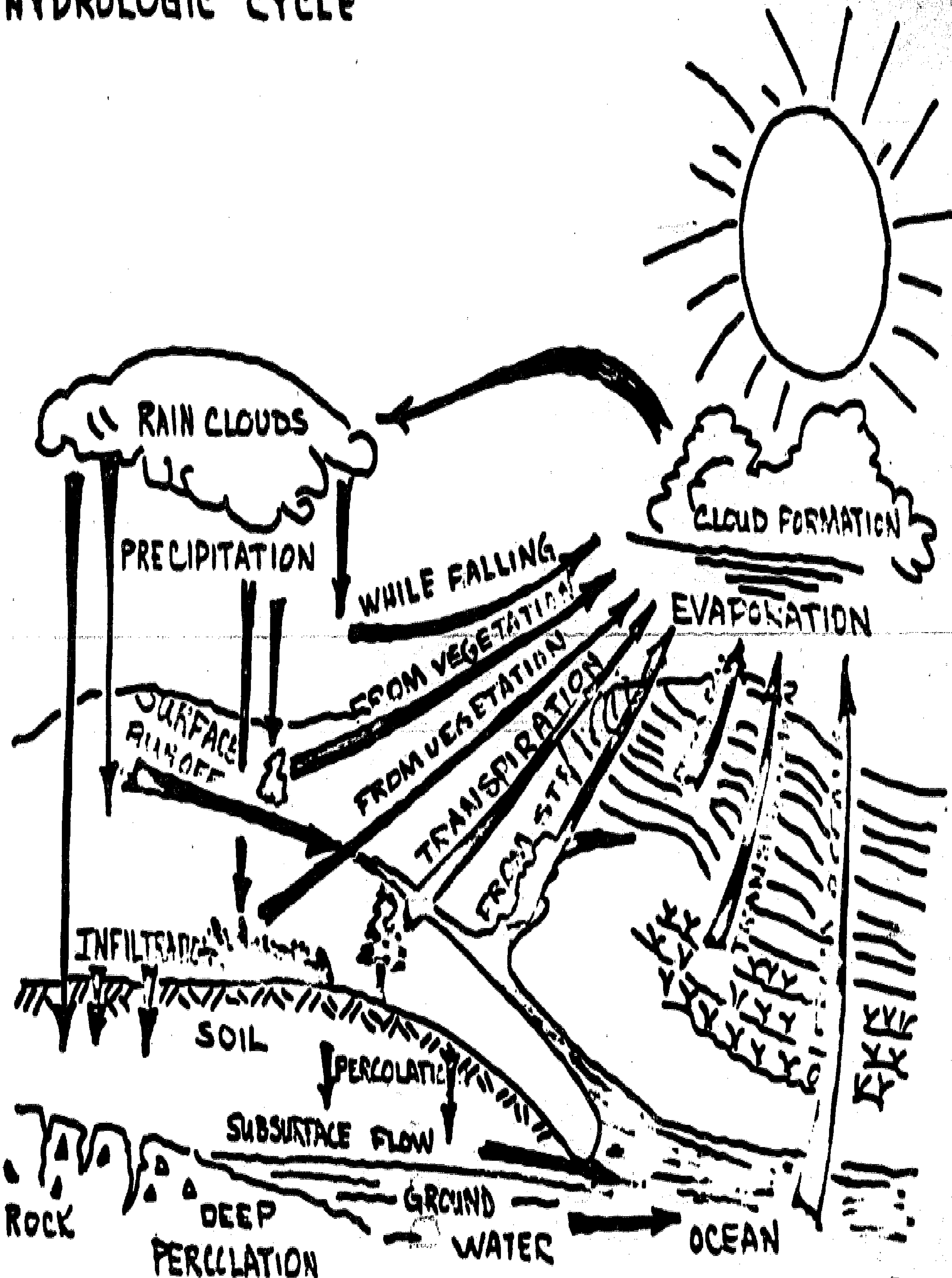
NOTE: You may wish to have the class split up. Half doing #1 and half #2.

PROCEDURE: 1) Construct a diagramatical sketch of the hydrologic cycle as it occurs in nature (on a macro-scale). Think of yourself as a water molecule in the ocean (or cloud, etc.). As you evaporate from the ocean (or fall from the cloud) think of the many options you have both before and after (you evaporate or fall). Draw in these segments and label them accordingly until you feel you have exhausted the options possible.

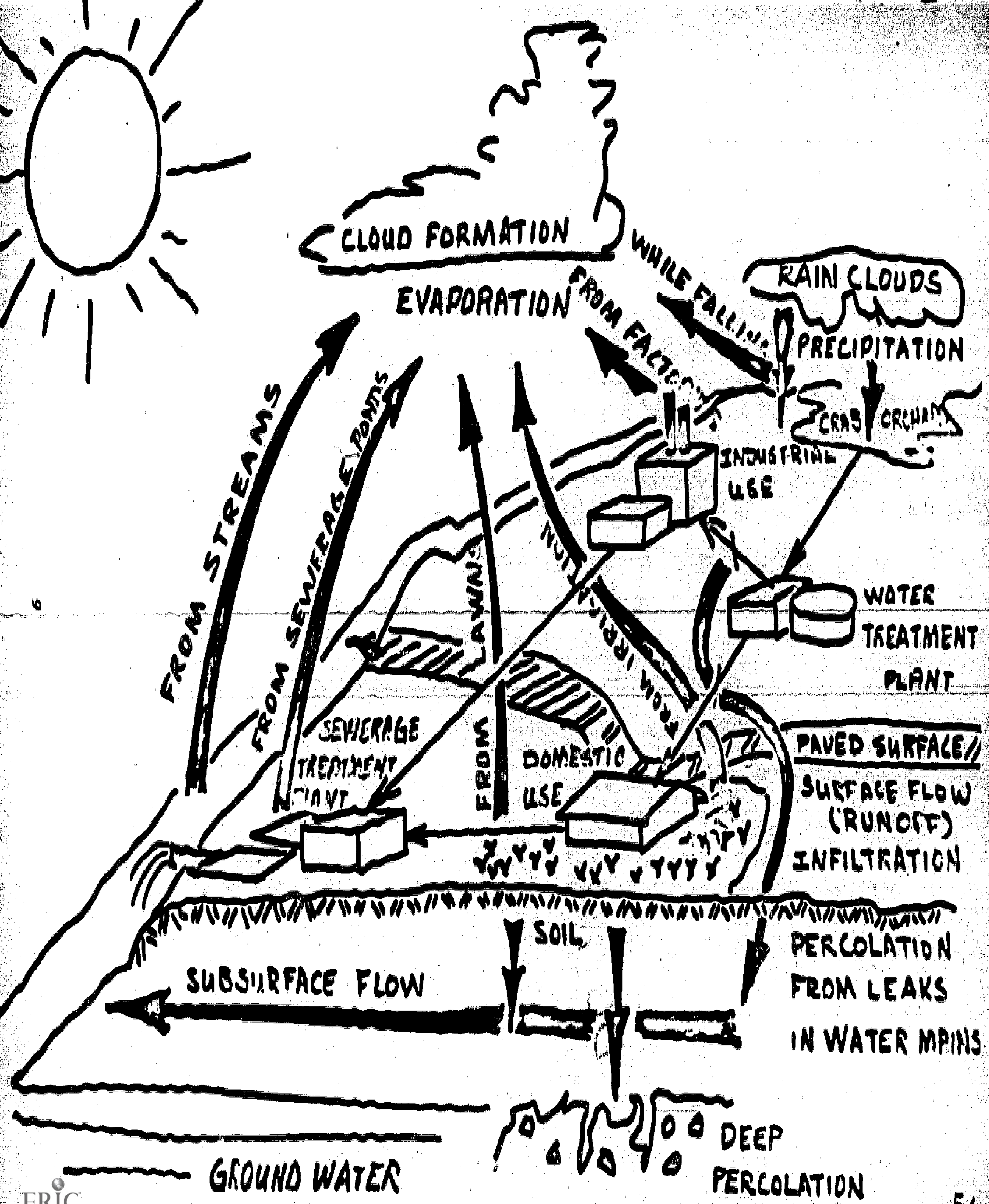
2) Do the same as above only this time the options possible in and around your community. (a micro-scale). Instead of sketching how the hydrologic cycle naturally occurs sketch the segments as they apply specifically within the city. (i.e. Instead of a tree we may end up in a factory, etc.)

3) The sketches accompanying this lab should be representative of what the students should attempt to attain.

# THE HYDROLOGIC CYCLE



# A MICRO-HYDROLOGIC CYCLE



LESSON 5

CONCEPT: Freshwater Ecology (analysis of the chemical and biological framework of a stream and their direct relation to water quality standards.

MATERIALS: Materials for this section are given with corresponding experiments.

INTRODUCTION: No study of water (or watersheds) would be complete without a comprehensive field survey of what actually exists in a given stream. Laboratory work investigating field conditions fulfills a variety of important objectives.

1) It gives the student an opportunity to relate concepts, taught in the classroom, to the outdoor environment.

2) It allows the student to see first hand the interrelationships of natural cycles. How everything is connected to everything else. (For example, how a storm might effect erosion, runoff, streamflow, and biological and chemical factors including man himself

3) It gives the student an opportunity to operate experiments in a scientific manner. Perhaps opening ideas for possible career education.

4) Data analysis provides real life examples of the biological and chemical makeup of a freshwater stream.

5) Indicators in above analysis (i.e. pesticides, low DO, insects tolerant of polluted conditions, etc.) give insights into the water quality of local watercourses.

6) Indicators sited above give clues to current problems and thereby open the door for the development and implementation of workable solutions.

NOTE: This is perhaps the most important lesson in this package. It gives the student something he can physically touch, smell, taste, observe, etc. And with a limited amount of effort opens the door to water problems and perhaps their eventual solutions.

PURPOSE: To allow the student to collect, analyze and record pertinent physical, chemical and biological data for the purpose of determining water quality. This analysis will continue for an extended period of time to allow trends to be established and to allow comparison with professional data already assimilated. Furthermore, this record of local stream data will, hopefully, prove helpful to the scientific community and water planning commission in their analysis and implementation of water management strategies.

PROCEDURE: This lesson is composed of various field and laboratory studies with the emphasis focused on how each relates to water quality standards. Samples and some work must be completed in the field to prevent errors in results. Other work can be accomplished in the

lab back at school. All results must be recorded on a master data sheet* and filed. This will allow comparisons from day to day, month to month, year to year and so on. If more than one school is involved (there should be) then each school will keep it's own file and results. This will allow comparisons from class to class and school to school.

Procedures will follow either of two methods. If a Hach (or any other scientifically acceptable) Kit is available then methods will follow those given with that specific kit. If a kit is not available then procedures will follow those outlined in this lesson.

Methods by which results were obtained should be noted for each experiment. (For example: Hach Kit, LaMotte Kit, or Lesson Guide.)

In addition to this sampling will only be conducted at various stations along Miller and/or Des Moines Creek. (Schools may wish to sample either one or both creeks. Separate files should be kept on each creek to avoid any mixing of data.) To avoid confusion exact location of sampling stations will be omitted. Teachers should set up a date with the environmental specialist to locate stations prior to any field investigations of this sort.

Field Studies include:

A. Physical
   1) Velocity of Flow
   2) Volume of Flow

B. Chemical
   1) Temperature
   2) Dissolved Oxygen
   3) Biochemical Oxygen Demand
   4) Bacteria, Coliform
   5) Nitrates
   6) Phosphates
   7) pH

C. Biological
   1) Surber Sample
   2) Ekman Dredge
   3) Basket Sample

Field Guide

A. Physical

1. Velocity of Flow:

(Information) - The rate (or velocity) of streamflow influences a great many factors in the aquatic environment.

a. For example, there is a direct relationship between the composition of the stream bed and rate of flow. A rapidly moving stream will carry along much debri, leaving only the larger heavier particles behind. In slower waters, the bottom debris contains smaller and lighter particles.

b. Rate of flow also requires adaptation by certain plants and animals. Only plants and animals suitable for existence in a constant, often quite violent, motion can survive here.

*See sample of Master Data Sheet in following section.

c. The amount of Dissolved Oxygen available to aquatic organisms is largely controlled by the amount of agitation or aeration of the surrounding water. Fast running turbulent streams are usually higher in D.O. than slow moving more placid watercourses.

d. Temperature is also affected by the velocity of flow. Aeration by turbulence and increased velocity causes greater evaporation to occur (by stirring or spreading water out over a larger surface area). This evaporation causes cooling thereby affecting temperature.

Lab Section: Materials and procedures for field work on Velocity of Flow can be found in "Freshwater Ecology."

Method 1

Materials - a) stop watch
b) known length of string
c) buoyant object such as an orange or a styrofoam ball

Procedure - Stand near the center of the stream and, having set the stop watch, drop the object on the end of the string into the water. At the moment the object hits the water, start the watch. As soon as the string becomes tight, stop the watch. During this procedure, the hand holding the string should be as near as possible to the surface of the water.

You have now recorded the time and the distance (length of the string). If the string is measured in meters, you can very easily compute the velocity in meters per second. Repeat this procedure 3 or 4 times and average the results.

Method 2 - The Thrupp Method

Materials - a) straight flat bar or metal or wood
b) two nails or pegs
c) meter stick

Procedure - Set up the apparatus as shown in Figure 5.6. Place it in the water with the nail end upstream, holding the bar and meter stick parallel to and slightly below the surface of the stream. Ripple

patterns will be set up as shown in Figure 5.7. As the stream velocity increases, the intersection of the wave patterns (B) will take place farther down the meter stick. Measure the distance AB in cm. Calculate the surface velocity in meters per second as follows:

When $P_1P_2 = 10$ cm, use $v = 0.1555\ D$

When $P_1P_2 = 15$ cm, use $v - 0.1466\ D$

In these formulas, v - surface velocity in meters per second and D = distance AB in centimeters.

NOTE: This method will give you only surface velocity and cannot be used in very slow-moving streams.

2. Volume of Flow:
   Many of the same factors which are influenced by flow velocity are influenced by volume.

   A. For instance, the composition of the stream bed is affected by large amounts of water. A large volume of water will move larger amounts of bottom material. This would in turn affect plant and animal habitation as well as the amount of food transported and available to these organisms.

   B. A greater volume of water can withstand greater amounts of pollution. This is possible simply because of the dillution factor. More water allows greater dillution which increases the speed of self-purification.

Lab Section: Materials and procedures for field work on Volume of Flow can be found in "Freshwater Ecology."

Materials: a) stop watch
b) float
c) tape measure

Procedure: Determine the following values:

t--the time in seconds required for the float to travel a measured section of a stream
l--the length in meters of the stream section
w--the average width in meters of the stream section
d--the average depth in meters of the stream section

To compute the rate or volume of flow in cubic meters per second, use the formula

$$r = \frac{wdal}{t}$$

where a is a constant. The value of a is 0.8 if the stream bed is composed of rubble or gravel, and 0.9 if the stream bed is quite smooth (sand, mud, silt, or bedrock).

If you have already measured the stream velocity in meters per second by one of the methods outlined in Section 5.13, use the formula

$$r - wdav$$

where v is the velocity of the stream.

PROBLEM: If you measure the volume of flow for the same stream in a very wide section and in a very narrow section, will the two values differ? Give your reasons for your prediction. Now measure the values. Was your prediction correct?

B. Chemical

1. Temperature

Temperature plays an important role in two specific areas.

The first area which temperature influences directly is species diversification. Each stream has certain plants and animals that are best suited to a particular type of environment. This environment depends a great deal on temperature and temperature extremes. If there is a radical change in temperature, the environment also changes as do the plants and animals best suited for that environment.

Temperature also affects the dissolved oxygen level of a stream. Cold water usually contains more DO than warm water. A change in temperature may result in a change in DO. Since osygen is required by all living things any change in its abundance may have a direct effect on all "living" activities.

Lab Section: Materials and Procedure for field work on temperature.

Materials: Most non-clinical and non-cooking thermometers will suffice, Readings should be made in degrees Centigrade.

Procedure: For waters less than 5' in depth, readings at the surface are usually sufficient.

2. Dissolved Oxygen

Oxygen is required by all living things. Oxygen in water is necessary for the breakdown of wastes and waste material. The amount of oxygen (Dissolved Oxygen -DO) in water is very critical. Man often forgets how important oxygen is because there is always enough oxygen in

the air we breathe. In water, however, this is often not true. Air contains approximately 200,000 parts per million oxygen whereas good clean cold water only contains about 10 ppm. The concentration of oxygen is critical and varies with temperature and atmospheric pressure.

The effect of wastes (those that can be oxidized or broken down) on streams, the suitability of the water for fish and other organisms, and the progress of self purification all can be measured by DO determination.

NOTE: DO samples should be processed immediately because oxygen reactions continue in the stream or in the bottle.

Lab Sections: Materials and procedures for field work on Dissolved Oxygen. (See Hach Kit)

3. Biochemical Oxygen Demand

This is a basic procedure used by sanitary engineers to evaluate the effects of domestic sewage and industrial wastes in treatment plants and receiving waters (creeks, streams, rivers, etc.)

During the time organic matter in sewage (or any other water) is being changed by bacteria from the decomposable to the next stage, oxygen is being used. The amount of oxygen used by this action is called the BOD of the sample. The BOD test determines the amount of oxygen required to stabilize the organic material in a sample. Because of the relationship between the organic food (human wastes, garbage, etc.) bacteria, and oxygen, this test indicates whether a sewage is strong or weak, and also provides a means for measuring how effective treatment processes are. Tests on final sewage treatment plants effluents provide some indication as to how this effluent will affect the stream or other receiving water.

Lab Section: Materials and Procedures for field work on BOD (See Hach Kit)

4. Bacteria (Coliform)

The coliform bacteria test is for a group of bacteria that live in the intestines of humans and other animals and occasionally are found in soil. When present in water they are the result of pollution or contamination

by sewage or surface water even though they are not harmful in themselves. The test then is not for specific disease causing organisms (germs) but rather for the family of intestinal bacteria which accompany nearly all waterborne disease germs.

Lab Section: Materials and Procedures for field work on Coliform Bacteria (See Hach Kit)

5. Nitrates

Nitrate represents the most completely oxidized state of nitrogen commonly found in water. High levels of nitrate in water indicate biological wastes in the final stages of stabilization or run-off from heavily fertilized fields (commercial fertilizers contain nitrogen in the form of nitrates.)

Nitrate-rich effluents discharged into receiving waters can degrade water quality by encouraging excessive growth of algae. (As large concentrations of algae die, oxygen is used up in the decomposition process thereby reducing the dissolved oxygen content of the water and therefore affecting water quality.)

Lab Section: Materials and Procedures for field work on Nitrates. (See Hach Kit)

6. Phosphates

Phosphates are widely used in municipal and private water treatment systems and often occur in natural waters.

Phosphates enter the water supply from agricultural fertilizer run-off, water treatment, and biological wastes and residues. Industrial effluents related to corrosion and scale control, chemical processing, and the use of detergents and surfactants contribute significantly.

A certain amount of phosphate is essential to organisms in natural waters and is often the limiting nutrient for growth. Too much phosphate can produce eutrophication or over-fertilization of receiving waters, especially if large amounts of nitrates are present. The result is the rapid growth of aquatic vegetation in nuisance quantities, and an eventual lowering of dissolved oxygen content of the lake or stream due to the death and decay of the aquatic vegetation.

Lab Section: Materials and Procedures for field work on Phosphates. (See Hach Kit)

7. pH

The pH test is a measurement of the intensity or activity of acid or alkaline (basic) materials in water. A pH of less than 7.0 is acid, while 7.0 is neutral and above 7.0 is alkaline. The entire scale runs from 0 to 14; therefore 3 would be very acidic and 10 would be very basic (or alkaline.)

Most living things do best in a pH range between 6.0 and 8.0. Drinking water is best at a pH of from 7.2 to 7.6. If pH gets much below 6 or above 8, very little will grow and water becomes essentially sterile.

Lab section: Materials and Procedures for field work on pH (See Hach Kit.

C. Biological

Benthic (or bottom) Studies:

1. Benthic organisms are considered good indicators of long term water quality conditions. They are sensitive to environmental changes and manifest these changes in their community composition, species abundance and diversity.

2. An oligotrophic (usually low in plant nutrients and high in dissolved oxygen) clean water stream has flora and fauna indicative of the clear water conditions (high quality).

3. Likewise, the ecology of eutrophic streams indicates (through identification of dominant species) the relative degree of eutrophication* and/or pollution

*Eutrophication - Usually referred to as the "natural" dying of a lake or waterbody. Usually indicated by high nutrient levels (algae, etc.) and low dissolved oxygen content. The eutrophication process may be greatly speeded up by man-made pollutants. These organic pollutants increase the nutrient load of a waterbody tremendously. As these nutrients decompose, oxygen is used up. If load is too great the dissolved oxygen content may reach zero resulting in the breakdown of the natural system and death to all its inhabitants.

Table #I
Insects Associated with Oligotrophic (Clean Water) Conditions: High Quality

| Common Name | Order |
|---|---|
| Stoneflies | Plelotera |
| Mayflies | Ephemeroptera |
| Caddisflies | Trichoptera |

Organisms linked with organically polluted environments are listed in Table II. The presence of these organisms is not necessarily due to pollution, but are tolerant to polluted conditions.

Table #II
Insects Associated with Polluted Conditions: Low Quality

| Common Name | Family |
|---|---|
| Midge fly larva | Tendipedidae |
| Bloodworm | Lumbriculidae |
| Sludgeworm | Tubificidae |
| Sewagefly larva | Bsychoda |
| True midges | Chironomidae |
| Blackflies | Simulidae |

The quality of a stream or lake can be continually monitored by benthic organisms in a variety of ways.

1. As we have just noted, certain species prove to be indicators for certain water conditions. (Healthy - Oligotrophic or Unhealthy - Eutrophic conditions)

2. Just as individual species (and their relative abundance) can be indicators of water quality, the diversity of different species proves to be likewise helpful.

   a. This is to say, that under most circumstances a high diversity of species yields high quality water whereas, water with low diversity is likely to be low in quality also.

   b. A Diversity Index is a method of identifying water quality. The diversity index of a stream equals the number of families divided by the natural logarithm of the total number of organism(s) per square foot (D.I. = # Fam./$\text{Log}_e$ Total #)

c. A diversity index of 3.5 and larger is considered to be indicative of a healthy, balanced community of organisms. A D.I. of 3.5 or less is indicative of eutrophic or unhealthy conditions.

For example:

| | | | |
|---|---|---|---|
| # Families | = 14.00 | # Families | = 4.00 |
| Total # | = 17.70 | Total # | =85.00 |
| Log total | = 2.28 | Log total | = 4.44 |
| D.I. | = 4.87 | D.I. | = 0.90 |
| (Healthy Ecosystem) | | (Unhealthy Ecosystem) | |

To yield consistent diversity index calculations consistent samples of study populations must be taken. Generally, this is accomplished by repetitively sampling the same area; by setting up sampling stations and by sampling the same amount of area with the same device or technique each time.

Benthic Sampling

The Surber Sampler: This apparatus should be used to sample riffle areas, where organisms are dislodged by hand from the rocks etc. within the square foot bottom frame of the apparatus. Riffle areas are those stretches of the creeks which have rocky bottoms and relatively fast currents.

Organisms are collected only once for each station and collection is restricted to the square foot frame resting on the bottom. Each sample should be carefully inspected and sorted in a clean tray. All living organisms should be collected and preserved for identification and counting back at school. Collection is separate from station to station and organisms should be labeled as such. For example: Collecting Jar #1 = Organisms from Surber Sample - Station #1.

The Ekman Dredge: For non-riffle areas, the bottom material and its inhabitants is collected with an Ekman dredge.

Organisms are separated from substrate material by passing the material diluted with water through a standard #30 sieve. As with the Surber sample, organisms are preserved for identification and counting at a later date. Samples from each station are kept separately and labelled as such.

The Basket Sample: Baskets are initially filled with rocks and sunk at sampling stations. (Be sure to mark its location). At monthly intervals these baskets are emptied and picked clean of all inhabitants.

Organisms, as before, are labelled accordingly and preserved for identification and counting.

Final Analysis and Recording

After experimentation is complete final results are to be logged on the Master Data Sheets* for each school.

*For example:

Master Data Sheets

NOTE: Master Data Sheets must be filled out for every field trip applying to this lesson plan. Only in this manner can general trends in water quality be identified. If more than one school is involved then comparisons are possible and these may help validify any scientific information gained. This is your chance to share your knowledge with others. Fill out your Master Data Sheets after results of each field trip are complete.

Miller Creek is designated a Class A quality stream. How do your results compare with the standards given. See: Washington Class A Water Quality Standards

MASTER DATA SHEET

## PHYSICAL PROPERTIES

| Date | Creek | Station # | Method Used (brief description) | Water Velocity | Water Volume |
|---|---|---|---|---|---|
| | | | | | |

MASTER DATA SHEET

CHEMICAL PROPERTIES

Name of Creek: Miller Creek

| Date | Station # | C° Temperature | Dissolved Oxygen | Biochemical Oxygen Demand | Bacteria (Coliform) | Nitrate | Phosphate | pH |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

MASTER DATA SHEET BIOLOGICAL PROPERTIES

Name of Creek:

Date: Method Used: Surber Sampler

| Family | Station #1 | Station #2 | Station #3 | Station #4 | Station #5 | Total |
|---|---|---|---|---|---|---|
| Bactidae | 157 | 91 | 126 | 118 | 167 | 659 |
| etc. | | | | | | |
| Diversity Index | | | | | | |

MASTER DATA SHEET — BIOLOGICAL PROPERTIES

Name of Creek:

Date:

Method Used: Ekman Dredge

| Family | Station #1 | Station #2 | Station #3 | Station #4 | Station #5 | Total |
|---|---|---|---|---|---|---|
| | | | | | | |
| Diversity Index | | | | | | |

MASTER DATA SHEET BIOLOGICAL PROPERTIES

Name of Creek:

Date: Method Used: Basket Sample

| Family | Station #1 | Station #2 | Station #3 | Station #4 | Station #5 | Total |
|---|---|---|---|---|---|---|
| | | | | | | |
| Diversity Index | | | | | | |

MASTER DATA SHEET BIOLOGICAL PROPERTIES

Name of Creek:

Date: Total Count: Surber Sampler, Ekman Dredge (At monthly intervals - Basket Sample should also be added - but be sure to check on space provided.)

Including Basket ________
(Check if yes - should occur once every month)

| Family | Station #1 | Station #2 | Station #3 | Station #4 | Station #5 | Total |
|---|---|---|---|---|---|---|
| | | | | | | |
| Diversity Index | | | | | | |

# WASHINGTON STATE CLASS A WATER QUALITY STANDARDS

(a) General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

(b) Characteristic uses. Characteristic uses shall include, but are not limited to, for following:

(i) Water supply (domestic, industrial, agricultural).

(ii) Wildlife habitat, stock watering.

(iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing and boating).

(iv) Commerce and navigation.

(v) Fish and shellfish reproduction, rearing and harvest.

(c) Water quality criteria.

(i) Total coliform organisms shall not exceed median value of 240 (fresh water) with less than 20% of samples exceeding 1,000 when associated with any fecal sources of 70 (marine water) with less than 10% of samples exceeding 230 when associated with any fecal sources.

(ii) Dissolved oxygen shall exceed 8.0 mg/l (fresh water) or 6.0 mg/l (marine water).

(iii) Total dissolved gas - the concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.

(iv) Temperature - water temperatures shall not exceed 65° F. (fresh water) of 61° F. (marine water) due in part to measurable (0.5° F.) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 90/(T-19)$ (fresh water) or $t = 40/(T-35)$ (marine water); for purposes hereof "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

(v) pH shall be within the range of 6.5 to 8.5 (fresh water) or 7.0 to 8.5 (marine water) with an induced variation of less than 0.25 units.

(vi) Turbidity shall not exceed 5 JTU over natural conditions.

(vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause actue or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

LESSON 6

CONCEPT: Water Resource Management (Approaches to the solutions of $H_2O$ problems)

MATERIALS: None

INTRODUCTION: Water resource management includes a myriad of activities undertaken to obtain, distribute, use, regulate, treat and dispose of water. Basically these activities are of three types.

1. Those concerned with

   a. Allocation and distribution of existing water supplies.
   b. Regulation by legal and economic means.

2. Those activities which seek to use existing supplies more effectively.

3. Those which are concerned with changing water yields; their quantity, timing (regimen), quality, or location.

   a. Quantity (Problems of absolute supply)
      Solutions: - Import water
      - Artificial control of weather
      - Desalinization
      - Reduction of evaporative losses

   b. Timing (Problems of regimen)
      - This includes extremes in streamflow, particularily floods
      Solutions: (Flood control) - increasing the capacity of the channel to handle excess flow
      - decreasing the volume of water so it does not exceed the capacity of the channel.

   c. Problems of water quality:
      Solutions: - Development of a different supply.
      - Treating the existing supply to make it usable.

PURPOSE: The intent of this lesson is to acquaint students with some of the basic problems and/or solutions of watershed management. Perhaps more importantly, however, to stimulate action and awareness in their own community water problems and provide the groundwork for active involvement.

PROCEDURE: The field work on Miller and/or Des Moines Creek has provided us information on the physical, biological and chemical framework of these watercourses. This information allows us some insight into the present status (quality, quantity, regimen, etc.) of each creek. As you discuss the following problems and solutions of watershed management continually focus your attention on how each might be applicable to your own water supply (i.e. Miller and Des Moines Creek). In other words, look at each problem on a local, personal basis (it is your water) and then try to come up with some workable solutions. Write them down as if they will be used - They may be.

A) There are essentially three areas of water resource management. The first of these is:

Stress: 1) Those concerned with allocation, distribution, and regulation of existing water supplies. NOTE: Throughout the U. S. most water resource problems involve social and legal problems of competing use.)

Ask: *Is there any examples within the State of Washington that apply to this problem of competing use.*

Answer: The Columbia River is a perfect example. Look on a map of the U. S. and see how many states border (and thereby share) this large river.

In addition to this, in the last few years there's been increasing political pressure to divert Columbia River water to the arid Southwest.

Ask: *What's your opinion? Discuss advantages and disadvantages. For example: One advantage is that it would help farming and food production. One disadvantage may be that anadromous fish (salmon, steelhead, etc.) runs, which depend on high flows to trigger migration and maintain suitable temperatures, would be destroyed or depleted. This would cause the loss of a very profitable and enjoyable fishing industry.*

NOTE: In each case be sure to weigh each side of the issue.

(2) The second area of water resource management is - Those activities concerned with using existing supplies of water more effectively.

Discuss: Local activities or methods which fall under this category and how they might increase efficiency of local water use. For example: (1) There is a water treatment plant on both Miller and Des Moines Creek. Treatment plants usually help purify polluted (unusable) water and then recycle it for a variety of uses. (2) Reservoirs act as storage areas where surplus water can be detained and then released at critical low flow (or drought) periods.

(3) Modifying water yields is the third and perhaps most extensive area of management. It's difficult to change one characteristic without changing the others, so alternatives must be looked at carefully.

a) Problems in Absolute Supply - many parts of the world simply suffer from insufficient water supply.

Ask: *Can you think of any alternatives for obtaining additional water.*

(NOTE: Here are four examples of what we're looking for. If you can think of more - great)

1) Importing: Bring in water from regions of surplus (i.e. Columbia River to the Southwest perhaps) Discuss: Problems involved. What about expense? Conflicts by consumers? Engineering problems? Keep the discussion open and free to ideas, examples

2) Weather modification: Increase rainfall. Cloud seeding.
Problems for Discussion:
(a) Reliability - can we depend on it? Cloud seeding is a complex subject. There must be clouds or a moisture saturated atmosphere before precipitation (artificial or not) will fall.
(b) Costs: Cloud seeding is expensive and doesn't work all the time.

3) Desalinization: The change from salt water to usuable fresh water.
Problems:
(a) Cost - Conversion is possible but the cost of water is 5-10 times greater.
(b) Practicality - Cities inland find it unrealistic and uneconomical to convert and transport desalinated water.

4) Reduce Evaporation: Save water by preventing evaporation before use.
Problems:
(a) Methods involved - 2/3 of all the water falling on the U. S. returns to the atmosphere before it reaches a stream. In addition, significant quantities are lost from streams, lakes, and reservoirs. To stop evaporation we must separate two things. Water and Energy. How? Build roofs over reservoirs, store water underground, etc.

(b) Problems of Regimen (Timing)

Many water problems are due to the variations in streamflow with time.

Stress:
1) Although absolute supply, dealt with previously, is not a local problem (Burien & Des Moines) Regimen is! In fact, this is perhaps the greatest problem concerning Miller and Des Moines Creeks. For this reason any problems and/or solutions found may be directly applicable to the current local situation. Make the students realize that this lesson is actually community involvement. Solutions or alternatives they come up with can (and should) be submitted to local water planning commissions

such as RIBCO* or Sea-Tac Community Planning Commission.

A comprehensive plan is being done on Miller and Des Moines creeks as well as the Green - Duwamish and Cedar - Lk. Washington drainage basins.

Citizens are asked to share their opinions, values and goals for the environment of these areas. Technicians alone cannot decide the quality of life for your area - you, as a concerned citizen, must make these decisions.

ADDRESS: R.I.B.C.O.
410 West Harrison
Seattle, WA 98119
Phone - 284-5100

(a) Floods: We cannot control all floods, but many high flows can be reduced by man so as to prevent serious damage and/or problems.

Stress: (1) Most floods share a common denominator - That is, a flow that exceeds the capacity of the channel.

(2) Flooding is not an uncommon occurance along Miller and Des Moines Creeks.

(3) This problem (flooding) is a major community issue right now.

(4) RIBCO is currently working (with citizen support) on a comprehensive watershed management plan for these same two watercourses.

(5) This is the student's chance to have a say in community action and help decide their own quality of life.

*RIBCO (River Basin Coordinating Committee) is an environmental planning effort which includes the study of water resources, urban runoff, solid waste management, land use and water quality.

Discussion:

The goal here is to come up with some valid workable solutions. Should the students desire (and they should) they can send any proposals to RIBCO or present them at a RIBCO community meeting in your area.

1) Begin by stating the two basic methods of flood control:

   a) Increasing the capac.t. of the channel to handle excess flow.
   Now let the students go. Let them discover and explore any possible alternatives. List them as you go. (Remember these are going to be submitted as real live workab·. solutions. Keep stressing this. It's not just idle work.)

   Alternatives the students find might include:

   1) Construction of levees to increase bank height.
   2) Dredging the channel to make it deeper.
   3) Developing a floodway (essentially a second channel)
   4) Increase speed of flow (channel straightening, removing obstacles, smoothing channel sides.)

   Discuss every alternative. How acceptable is it to the students? What are its problems, its advantages? Look for the best possible solution. Weigh the factors. (i.e. money, ecology, fish, people)

   b) Decreasing the volume of water so it does not exceed the capacity of the channel.
   (This essentially involves storage of water in one place or another. For example, reservoirs, ground water acquifers, ponds, etc.) Follow the same method as before. List and discuss alternatives as students come up with them.

C. Problems in Quality: Much of the water in the U. S. is unsuitable for many uses in its natural state and more has become unsuitable because of man-made pollution: The major alternatives where water quality is unsuitable for use are:

Stress: (1) Development of a different supply.
Ask: *Does this solve the problem? Does pollution go away?*
Answer: There is no away! Our earth is essentially a closed system (like the water cycle)
(2) Treating the existing supply to make it usable.

NOTE: We must not think of "usable" in terms of man only. He is only one part of the entire ecosystem. All other species, both plant and animal depend on water in someway or another.

Now Ask: *What are some reasons for poor water quality.*
HINT: Have the students refer back to their own experience in the field. What factors influenced the quality of the creek they studied?

Answers: Some important reasons for poor water quality include:

(a) Sedimentation
(b) Mans use of water as a receptacle of his wastes (i.e. sewage, grease, oil, phosphates, etc., etc.)
(c) Pesticides, herbicides and fertilizer salts (reach water as a consequence of other activities)

The students should list these and/or other reasons for poor water quality. In every case discuss each reason in terms of

(1) how it occurs
(2) who or what is responsible
(3) what are it's consequences
(4) what's the solution

For Example:

Sedimentation:

1) Usually the result of increased watershed erosion.
2) Any number of things may be responsible.

| Natural | Man-Made |
|---|---|
| landslides | poor farming practices |
| floods | road construction |
| earthquakes | clear cutting |
| | building on the flood plain |
| | in general - poor land management |

Consequences:

1) Fish and wildlife adversly affected.
2) Biotic productivity is reduced.
3) Water treatment costs increase.
4) Hydropower turbines wear out more quickly.
5) It fills reservoirs, reducing their capacity

Solutions:

1) Wise land management practices such as strip farming, holding ponds, stringent controls on road construction and building permits, no disruption of soil along streams, etc.

Final Topics

Stress: 1) The basic solution to water quality problems is the prevention of excess.

2) Each stream has the capability to cleanse itself of pollutants.

3) When we overbalance this capacity for self-purification water quality is reduced.

4) Prevention can be accomplished.

Many of the problems of poor water quality are the direct result of man. It is therefore up to man to either find solutions for these problems or to cease his contamination of our most important resource. It's Our Water, And Our Lives Depend On It.

EXTRA ACTIVITY: Make a list of clubs or environmental organizations in your area. Attend RIBCO community meetings and others. Voice your opinion. Become involved. Save the Earth.

GENERAL SUMMARY AND CONCLUSION

Miller Creek (and what we have done to the rain.)

*(1) Not long ago the same amount of water fell on the coastal forest as falls today, but there was no severe flooding. The water landed on the trees, slowing its fall to the forest floor. Some water evaporated from the leaves and the ground, returning to the clouds. Much of the water absorbed by trees was transpired back into the air as water vapor, making the forest cooler. The water reaching the ground was absorbed by the forest floor until it was saturated. The remainder then ran over the ground, rapidly reaching creeks and ponds. Water moving more slowly through the ground helped to hold the water level constant in the drier summer months by slowly releasing itself into creeks and ponds.

(2) The area was logged and grew back. People settled, their needs were satisfied by one road and a corner store with a gas pump. When the rain fell on fewer trees, more water ran over the ground and was eventually dammed by the roadway. Slight flooding occurred because of the increased runoff caused by the impermeable surfaces of the road and buildings.

(3) As more people moved into the area, the commercial district grew: first one road, then another, more gas stations, followed by shopping centers, hamburger stands, and offices, all of them with parking lots. This is where the area stood a few years ago. Fewer trees slowed the rain and it to the air. Water ran rapidly over the concrete and asphalt, poured off of roofs onto barren parking lots, and flooded onto the streets being mysteriously collected in holes in the ground. These storm drains concentrated the runoff and dumped it into the creek as fast as possible, polluted with gas, oil, and litter. Suddenly there was flooding although there was no more rain than before.

(4) The stream became a trickle in the summer because less water was absorbed in the soil to be slowly released. The vast hard surfaces of roofs and roads and parking lots sped the water into Miller Creek faster than it could accept it or transport it to the Sound. Roads and back yards are now flooding. If this situation is allowed to continue, it will get worse. More people in the watershed will demand more goods and services, and facilities for these will result in more roofs, parking lots and litter. The flooding will become more severe. The creek itself may be turned into a sterile concrete sewer designed to handle the maximum flow occurring only a few days a year. The rest of the year it will be unpleasant and useless.

(5) The responsibility for this situation does not belong to the business community alone. We build houses, roads, driveways; fill in yards and cut down trees. The problem developed little by little, and we must change many things to put the rain back where it belongs. We could establish "holding ponds" where runoff might naturally go, and be allowed to stand for a short time. The water could soak into the ground and could be released, slowly, back into the creek in the days after the

*NOTE: (1) etc. are on poster diagram.

rain. Buying this land would be cheaper than channelizing the creek, and the ponds would also provide beauty and recreation.

(6) Water falling on the roofs of buildings (especially very large ones) should be held there to evaporate, or be channeled into the ground through gravel "French Drains" and released slowly into the stream as a natural spring.

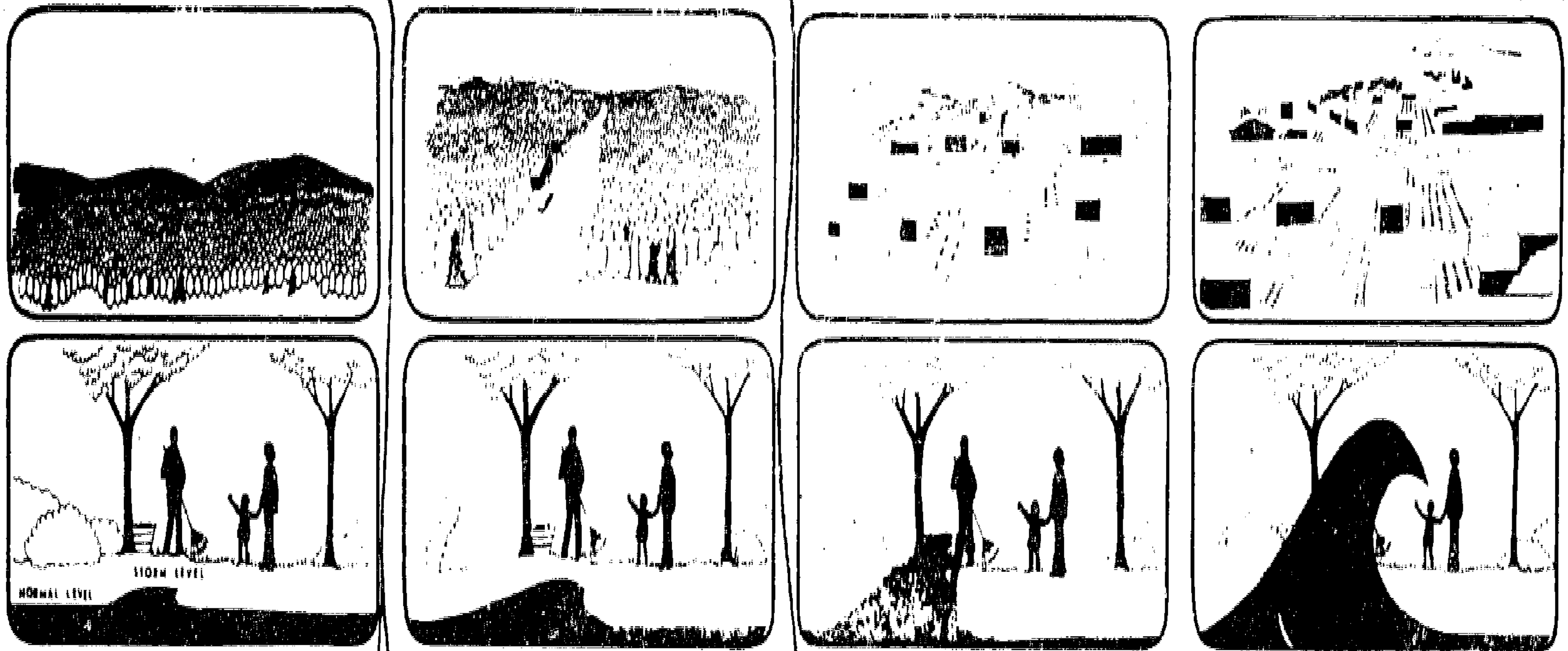
(7) The same could be done for parking lots, and even private homes.

(8) Gas stations add gas and oil to the water that their roofs and asphalt areas collect. They could trap all of their waste water, channeling it into large sand and gravel "fillers" under the surface. This would hold back much of the oil and grease, and also allow the water to filter slowly into the stream.

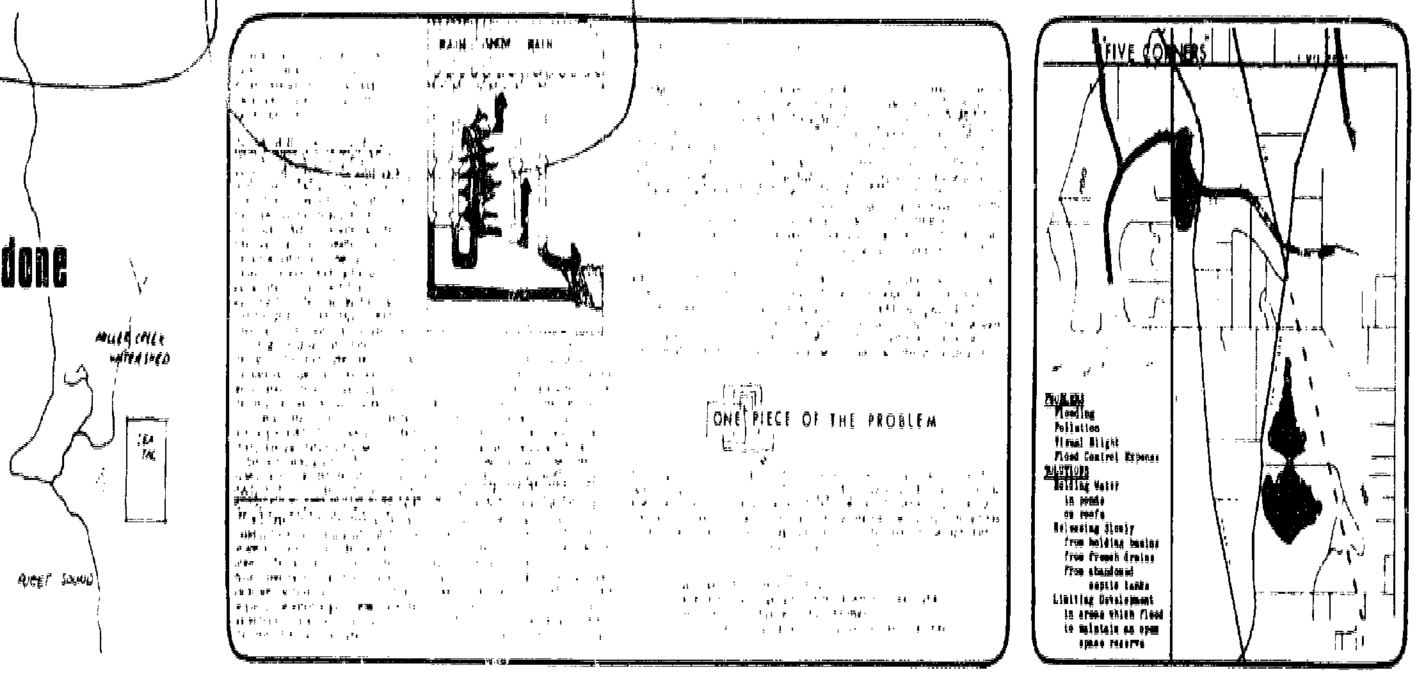
(9) Our roads our equally guilty. Rain joins with gas, oil, grease, and "tire dust" on the road, and runs to the edge where it is channeled directly to the creek. Why couldn't this water be collected and filtered through a French drain, and then be allowed to soak slowly through the ground till it finds its way to the creek.

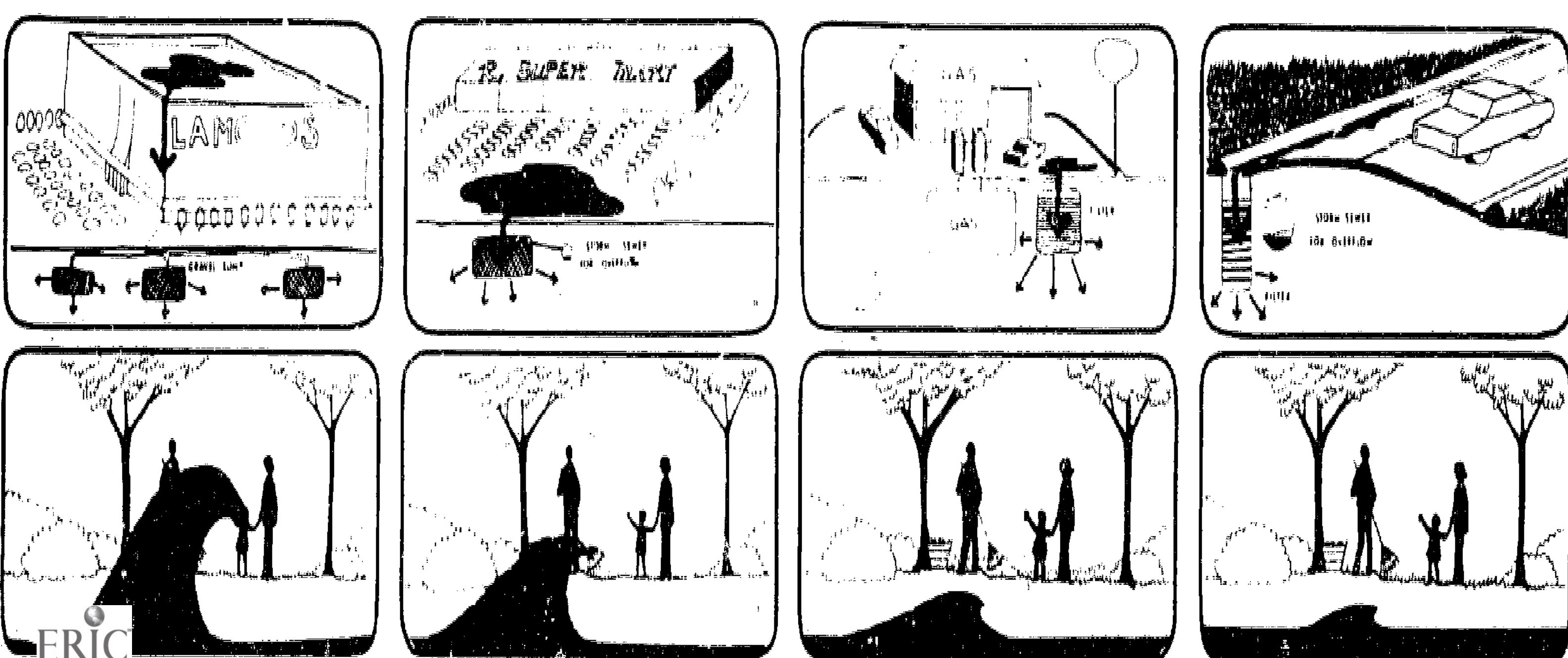
These suggestions are not complex. The science behind them is simple, and our society is capable of applying the solution. The problem is caring enough. Each citizen must do what he (or she) can with his (or her) home and business to help. We can act together to provide our government with money and ideas to help us solve our problems. We can legislate and zone to control development that would dump water faster into the creek. But we must start today to see the situation as it really is, and start to Act.

SOURCE: Landscape Architecture 403 Spring 1972
Department of Landscape Arch. U of W
Professors John Furtado and
Richard Untermann. Sonja Alvarea, Roy
Gatbunton, Peter Harvard, Do Jones, Ron
Stone




# what have we done to the rain?



3. What is the common term used to describe an area of drainage restricted by certain natural or man-made boundaries?
   a. water plaintain
   b. watercourse
   c. watershed
   d. water level

4. The process of water changing from a liquid state to a gas state is known as
   a. condensation
   b. convergence
   c. sublimination
   d. evaporation

5. Two things must be present for evaporation to occur. One is water, and the other is
   a. temperature
   b. energy
   c. air movement
   d. clouds

6. When you watch TV and drink ice water, what causes the moisture on the outside of your glass?
   a. condensation
   b. convection
   c. precipitation
   d. sublimation

7. Which of the following does <u>not</u> form clouds?
   a. convergence
   b. subsidance
   c. convection
   d. orographic lift

8. Condensation results from a
   a. increase in energy
   b. heating process
   c. cooling process
   d. increase in moisture

9. Salt, insoluable dust particles, and numerous chemical compounds are good examples of
   a. pollution
   b. condensation nuclei
   c. atmospheric fallout
   d. adiabatic waste material

10. Water reaches a stream channel by four primary routes. Which route is the first to show up on a hydrograph depicting streamflow?
   a. surface runoff
   b. sub-surface storm flow
   c. channel interception
   d. base flow

11. Which of the previously mentioned routes will show up last on the hydrograph?
    a. surface runoff
    b. sub-surface storm flow
    c. channel interception
    d. base flow

12. Of the two remaining routes, (the two not used as answers previously) the one showing the sharpest rise and highest peak on the hydrograph is most likely
    a. surface runoff
    b. sub-surface storm flow
    c. channel interception
    d. base flow

13. Two forces act together to move water down through the soil. One of these forces is
    a. centripetal force
    b. centrifugal force
    c. capillary force
    d. coriolis force

14. The force in question (13) exerts pressure:
    a. down
    b. up
    c. sideways
    d. all of the above

15. The force of gravity can best be described as a:
    a. variable (depending on the size of soil pores)
    b. variable (depending on the moisture content of the soil)
    c. constant
    d. constant (but cumulative per layer of water)

16. Infiltration capacity is the maximum rate at which water can infiltrate into the soil. Which of the following would <u>least</u> likely cause a change in this infiltration capacity?
    a. conduction
    b. compaction
    c. swelling of colloids
    d. air entrapment

17. The actual infiltration rate of water into the soil depends on
    a. soil texture
    b. soil structure
    c. nature of soil colloids
    d. soil moisture content
    e. all of the above

18. How does gravity affect storage of water in the soil? It has a
    a. positive effect by exerting a downward force on surface water thereby filling pores
    b. negative effect by draining pores
    c. null effect on storage, since it only influences infiltration <u>into</u> storage
    d. both a and b above

19. As water drains from the soil, the larger pores tend to give up their water first. This is primarily the result of
    a. gravity
    b. absorption
    c. capillary retention force
    d. air entrapment

20. What happens when a plant wilts?
    a. absorption force = capillary retention force
    b. gravitational force = air entrapment force
    c. centrifugal force = coriolis force
    d. gravitational force = absorption force

21. You're a farmer living on the plains of Kansas. You find yourself with an insufficient water supply. The least likely solution to your problem would be
    a. importing
    b. weather modification
    c. desalinization
    d. evaporation reduction

22. We can control most floods by
    a. increasing the capacity of the channel to handle excess flow
    b. decreasing the volume of water so it does not exceed the capacity of the channel
    c. both a and b above
    d. weather modification

23. The greatest water problem concerning the people of Burien in regards to Miller Creek is one of
    a. quantity
    b. quality
    c. regimen
    d. none of these

24. The basic solution to water quality problems is
    a. treatment
    b. immediate cessation of all pollution
    c. prevention of excess pollution
    d. a and c above

25. The total amount of water on earth is
    a. increasing
    b. decreasing
    c. staying about the same

26. All things being equal, which stream is likely to have the most problems with pollution?
    a. Stream P which is small and turbulent
    b. Stream L which has a very high volume of water
    c. Stream X which is calm and cold
    d. Stream Z which is very warm

27. You find a high concentration of nitrates in a water sample. What do you recommend in your report?
    a. The nitrate discharge should be stopped because it encourages algae growth.
    b. The nitrate supplements are probably working and should continue; nitrates fertilize water plants, providing more food for fish.
    c. The nitrate discharge should be stopped because they are poisonous pesticides.
    d. The nitrate discharge should be stopped because they are harmful bacteria.

28. What would you as a water analyzer do if you found Benthic organisms in a sample?
    a. Recommend that the effluents containing them no longer be dumped into the water by municipal sewage plants.
    b. Pressure farmers not to allow fertilizer runoff into the water.
    c. Call the Health Department at once.
    d. Study them, since they indicate water quality.

29. Which of these insects would you find in a clean stream?
    a. Stonefly, caddisfly
    b. Midge fly, blackfly
    c. Sludgeworm, sewagefly
    d. Bloodworm, blackfly